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(54) **LITHOGRAPHIC APPARATUS AND DEVICE MANUFACTURING METHOD INVOLVING A MEMBER AND A FLUID OPENING**

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CPC ***G03F 7/70341*** (2013.01); ***G03F 7/7085*** (2013.01)

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(57) **ABSTRACT**

An exposure apparatus including a movable table, a member, movably separate from the table and located on a top surface of the table, to provide a surface substantially co-planar with a top surface of an object in or on the table, a projection system configured to project a radiation beam onto a radiation-sensitive target portion of a substrate, and a liquid supply system configured to provide a liquid to a space between the projection system and the object.

19 Claims, 10 Drawing Sheets

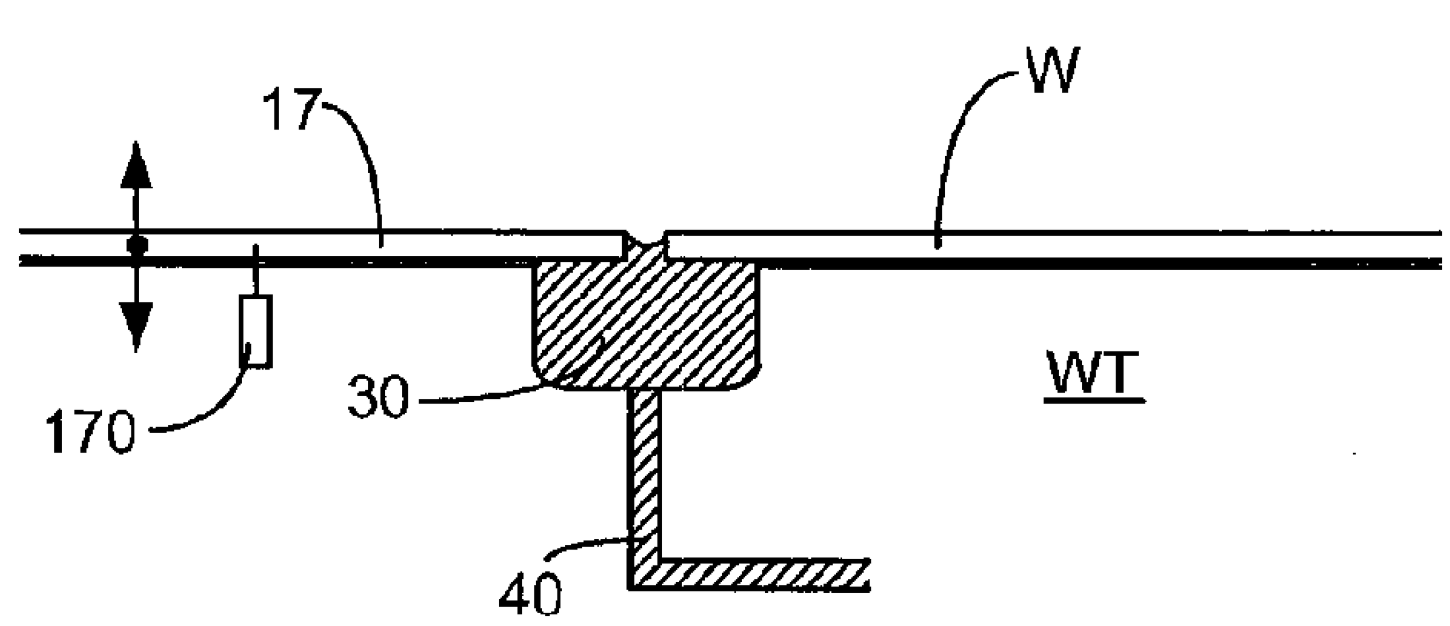

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Fig. 1

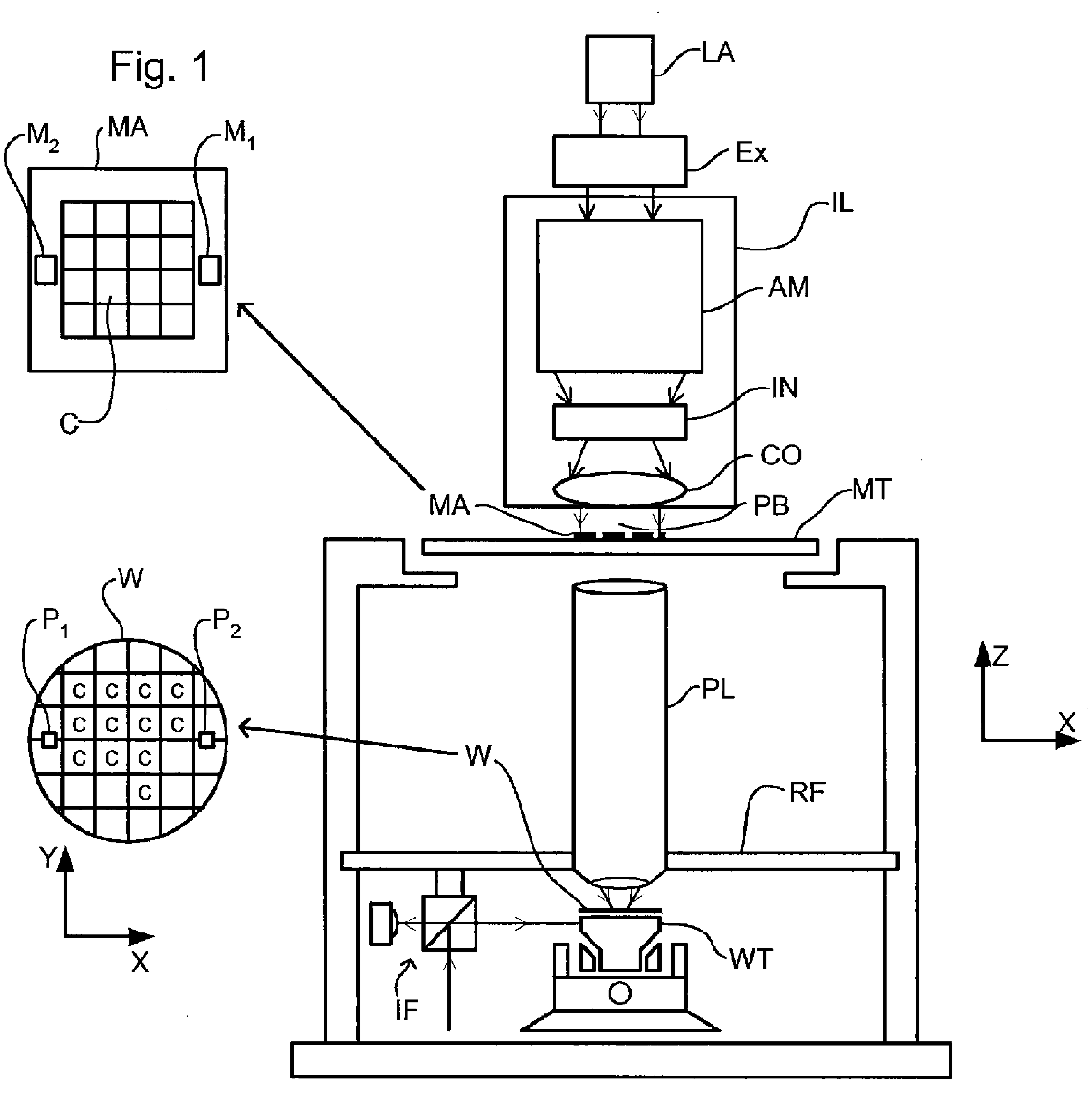
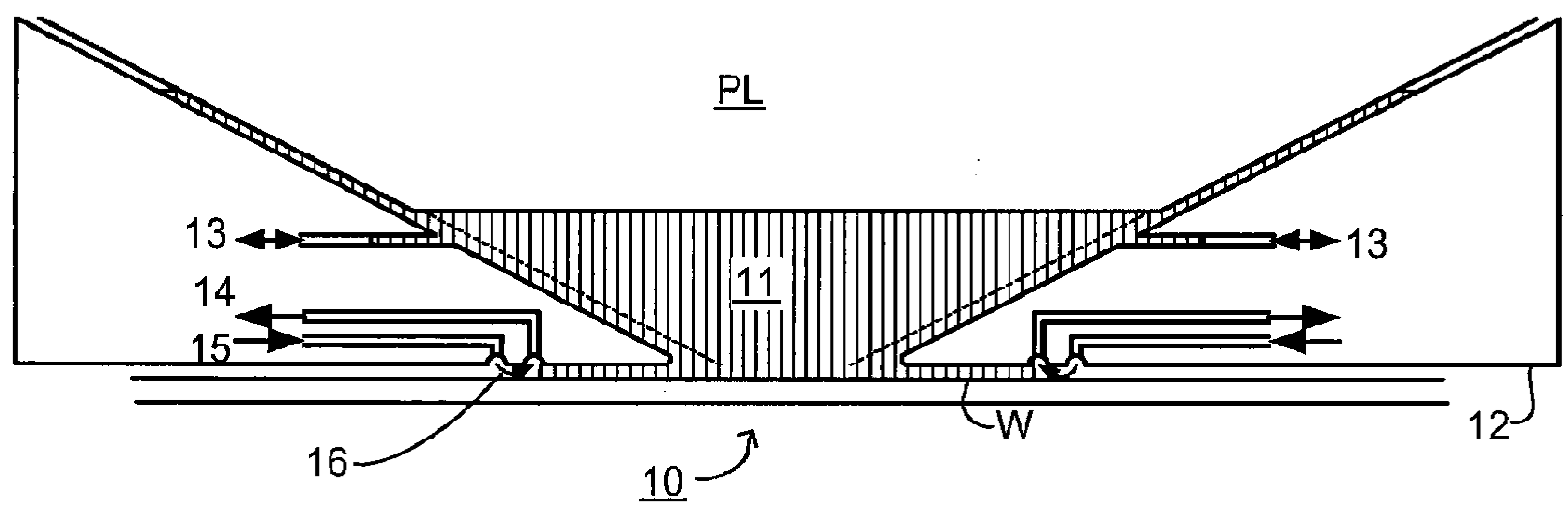


Fig. 2



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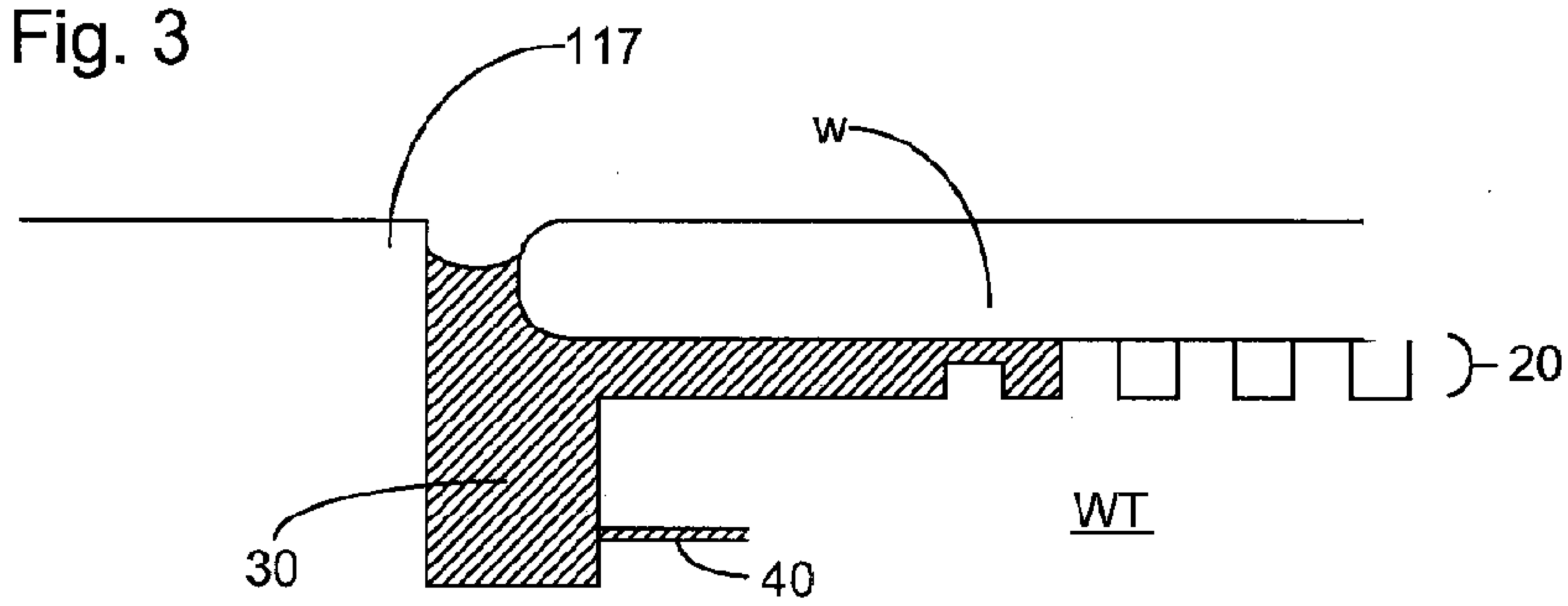

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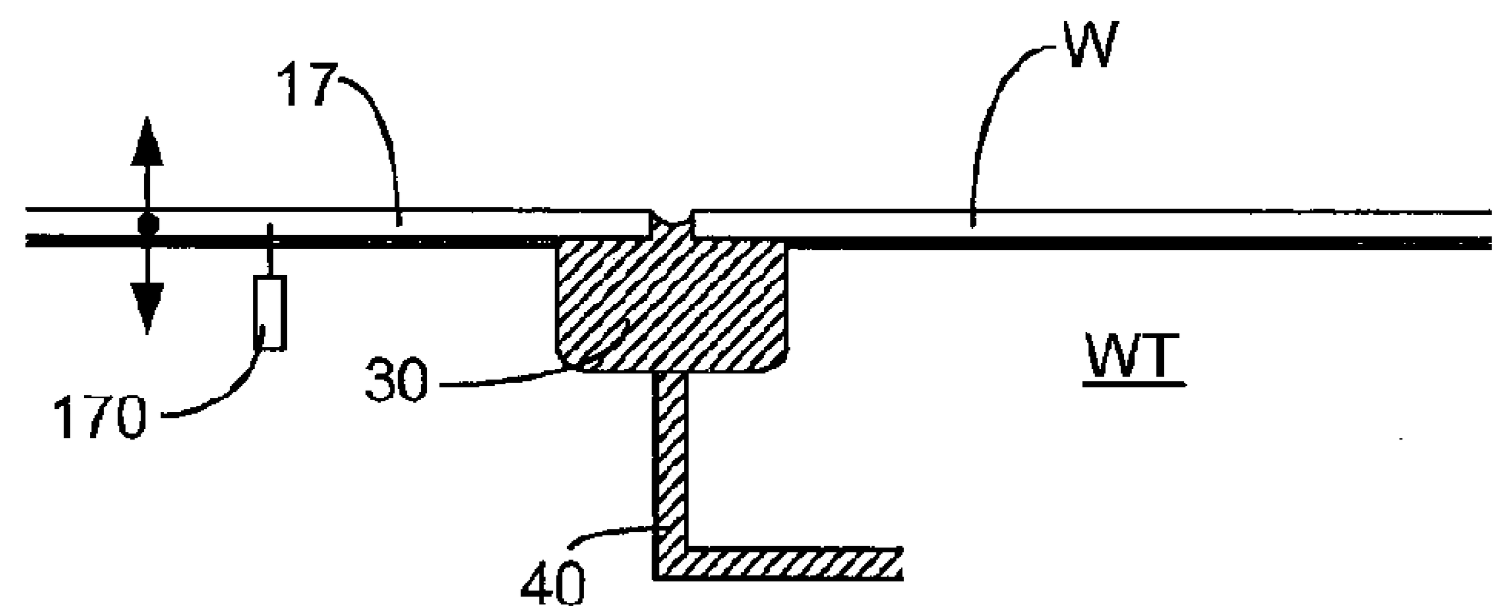

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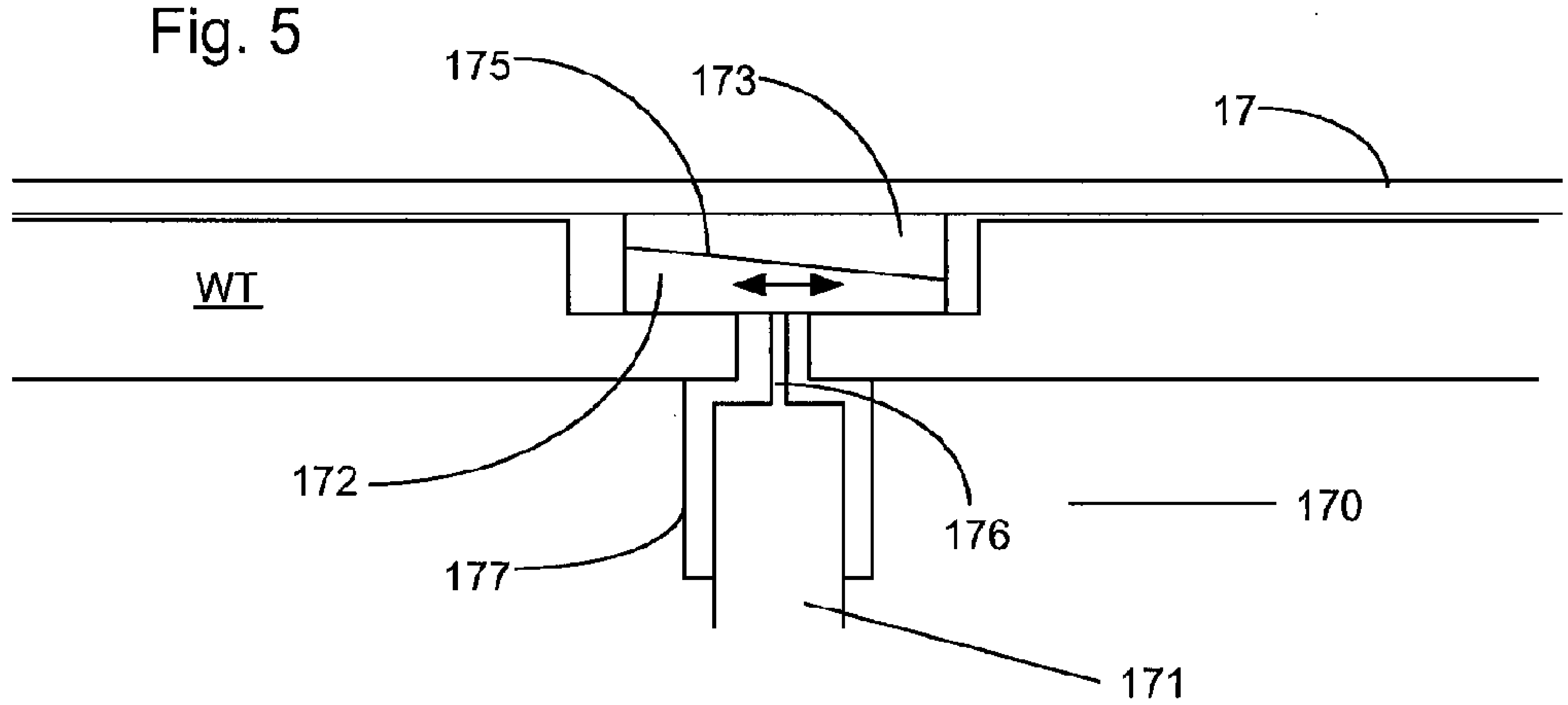


Fig. 6a

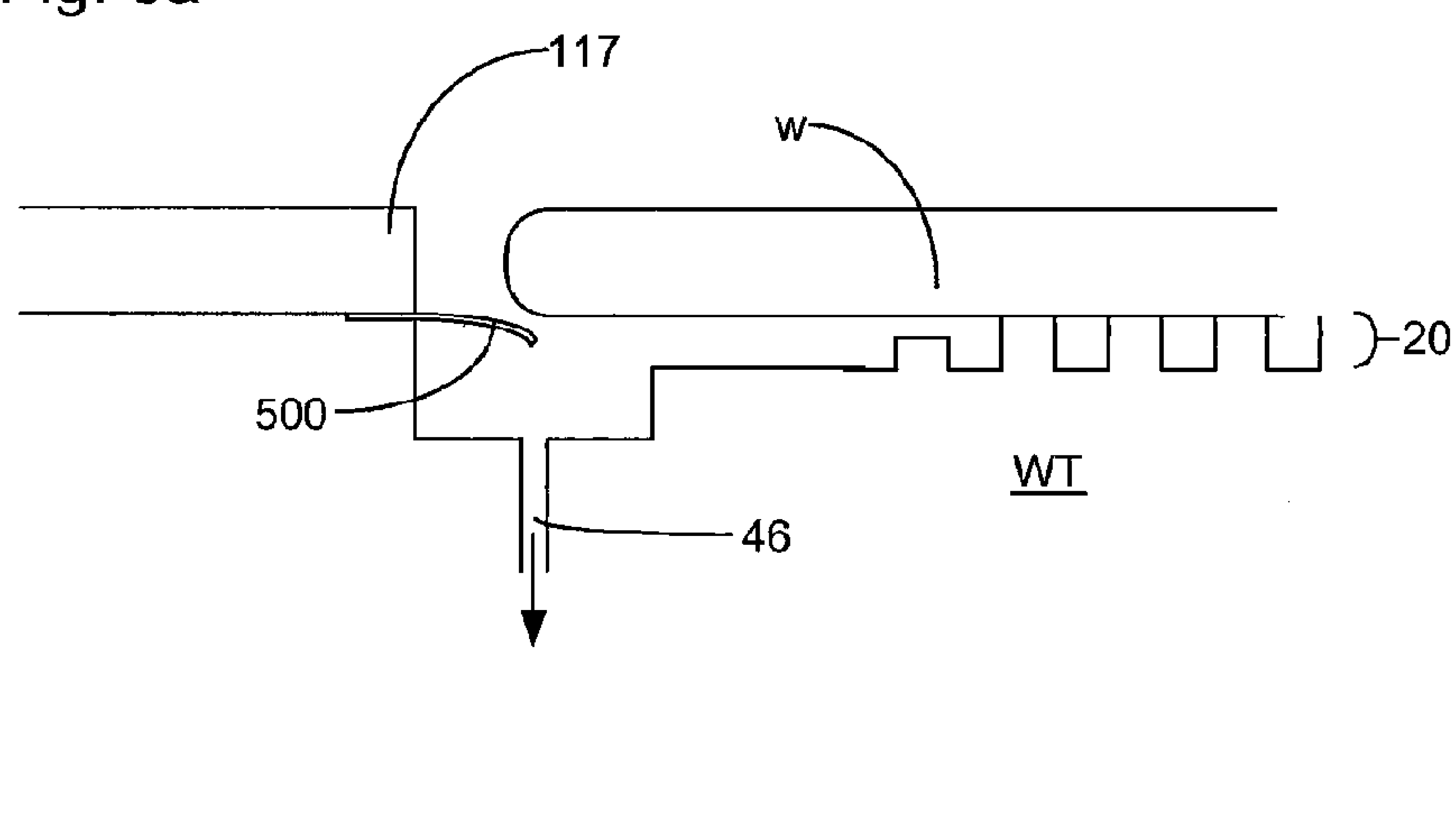


Fig. 6b

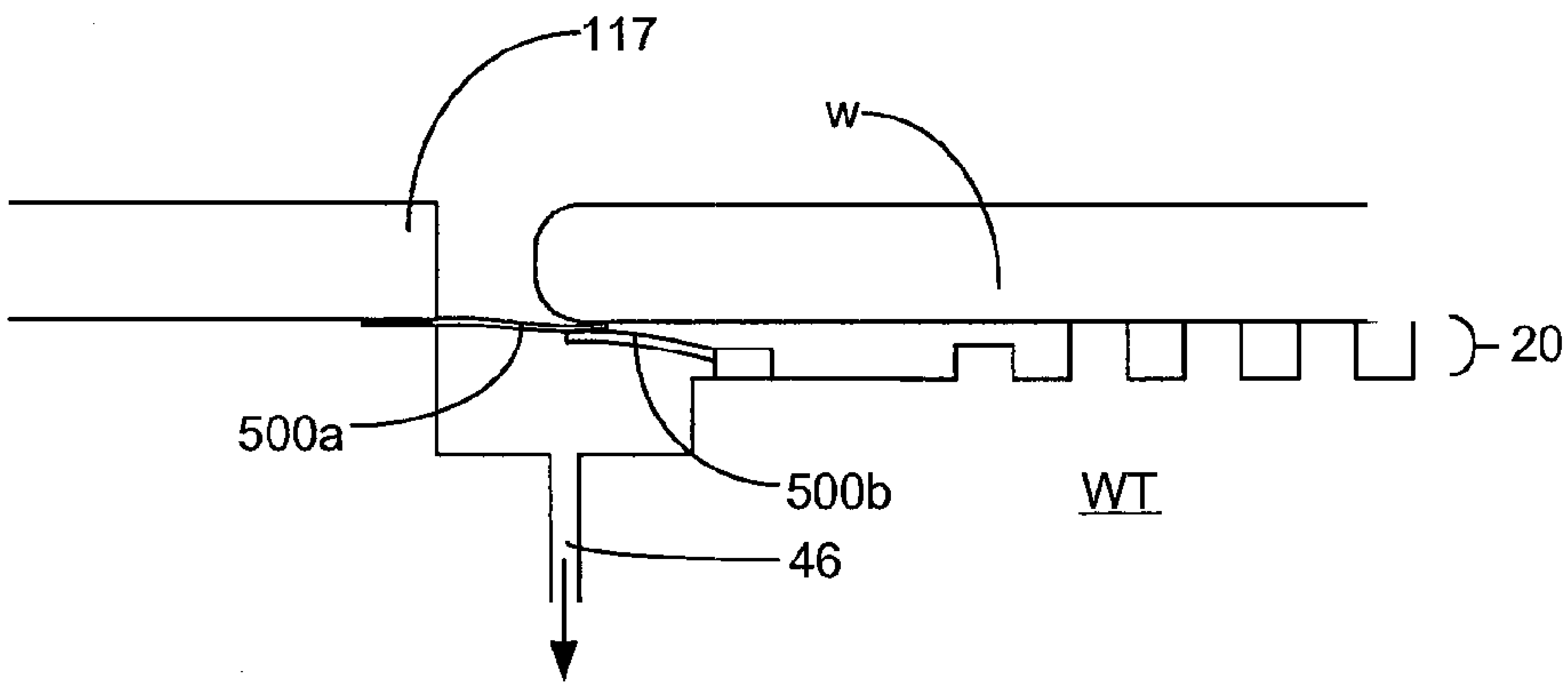
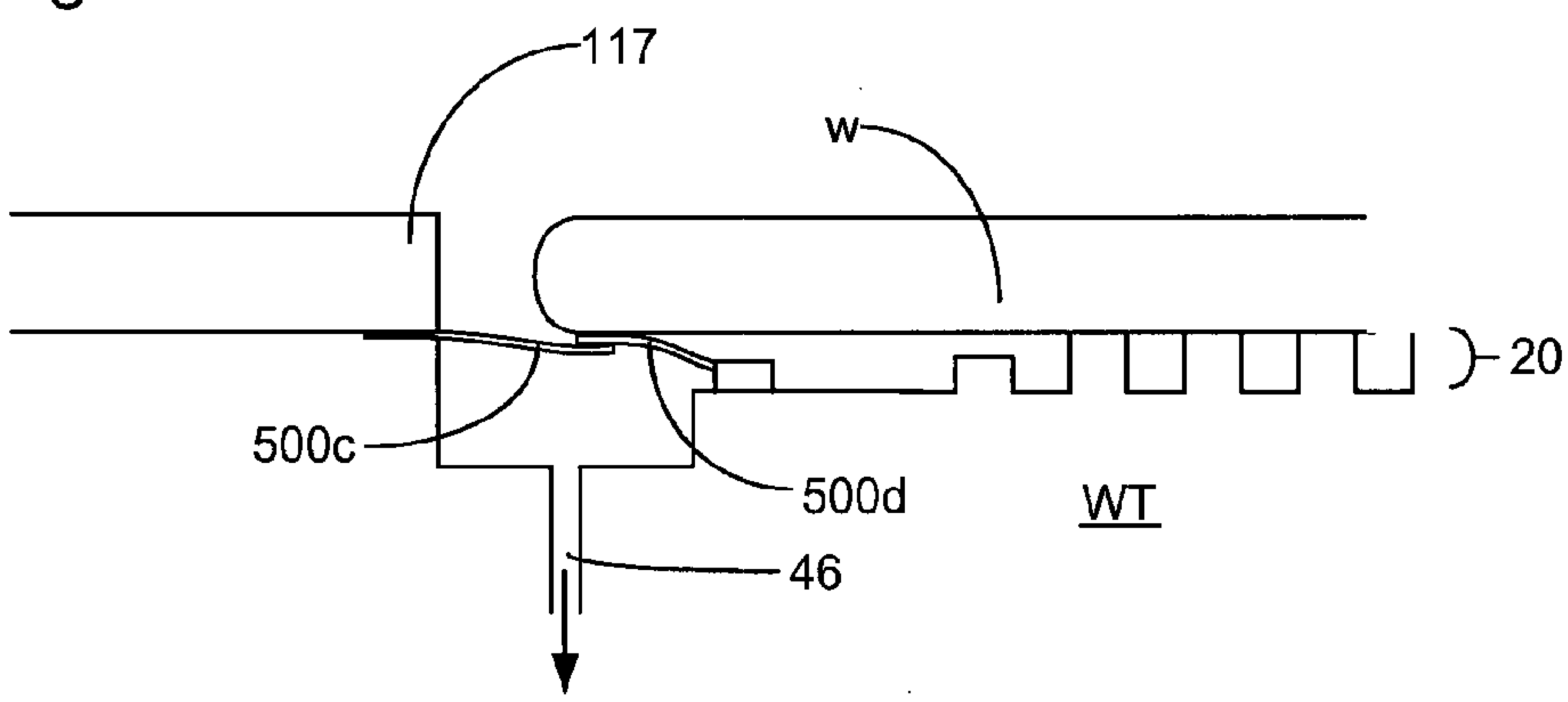


Fig. 6c



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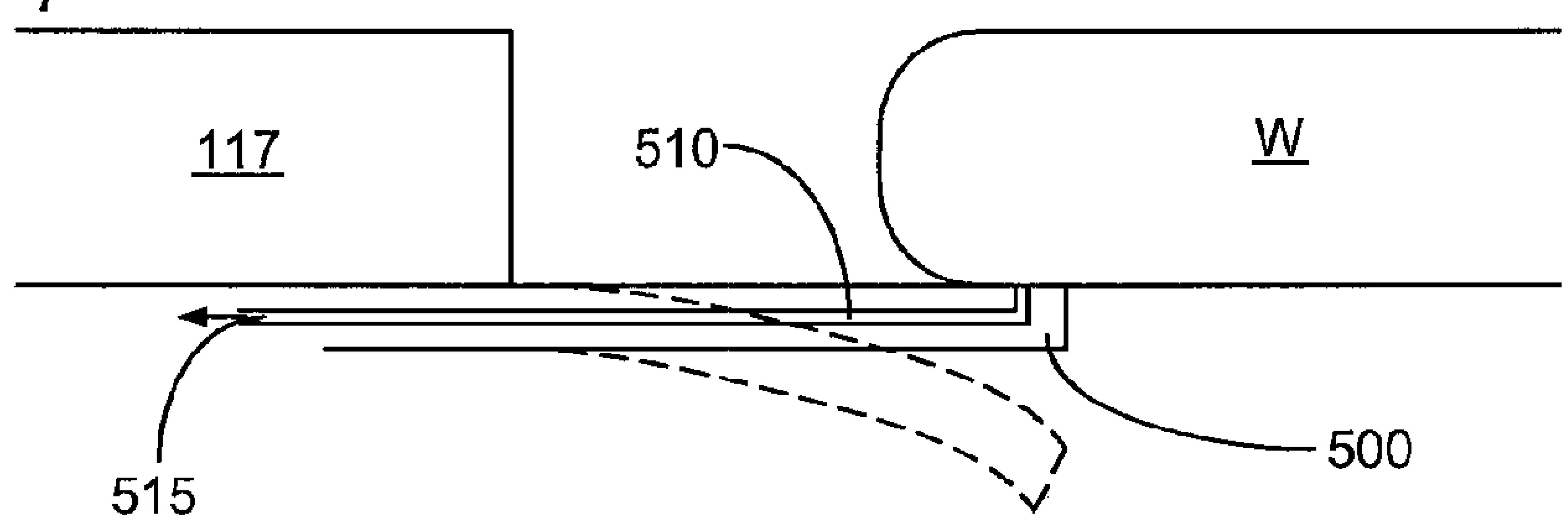

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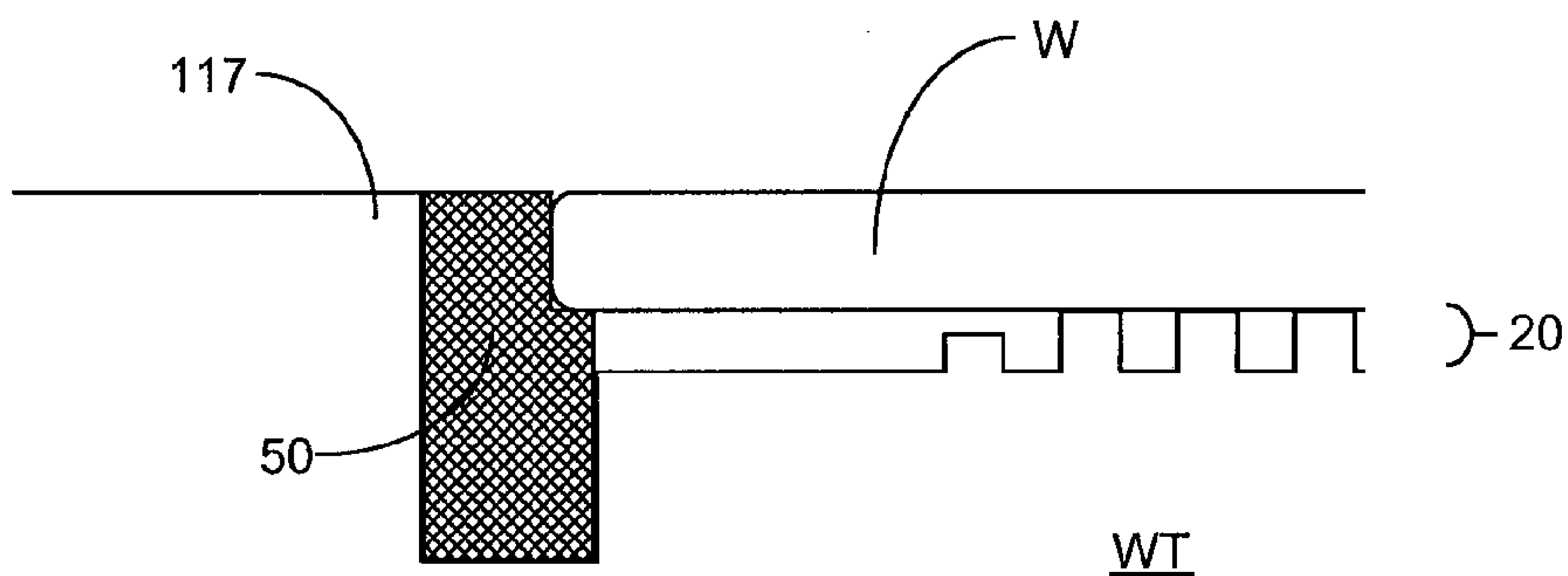

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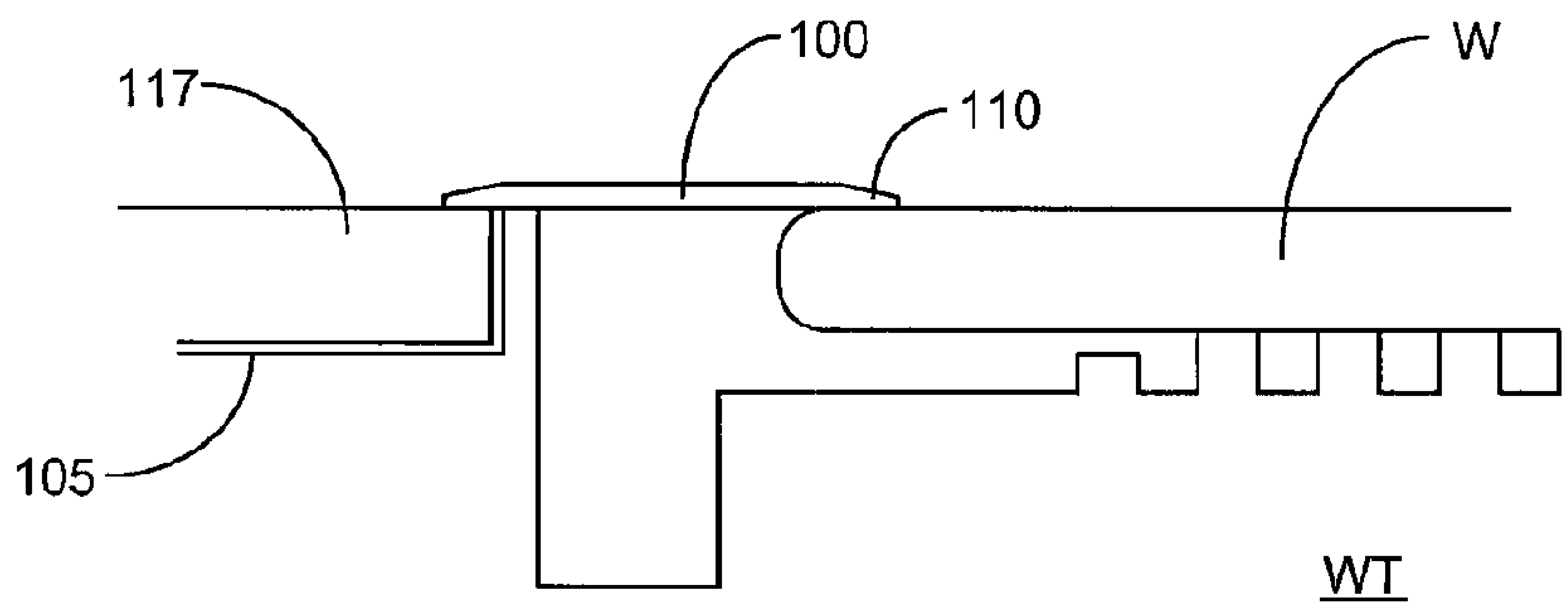
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Fig. 10

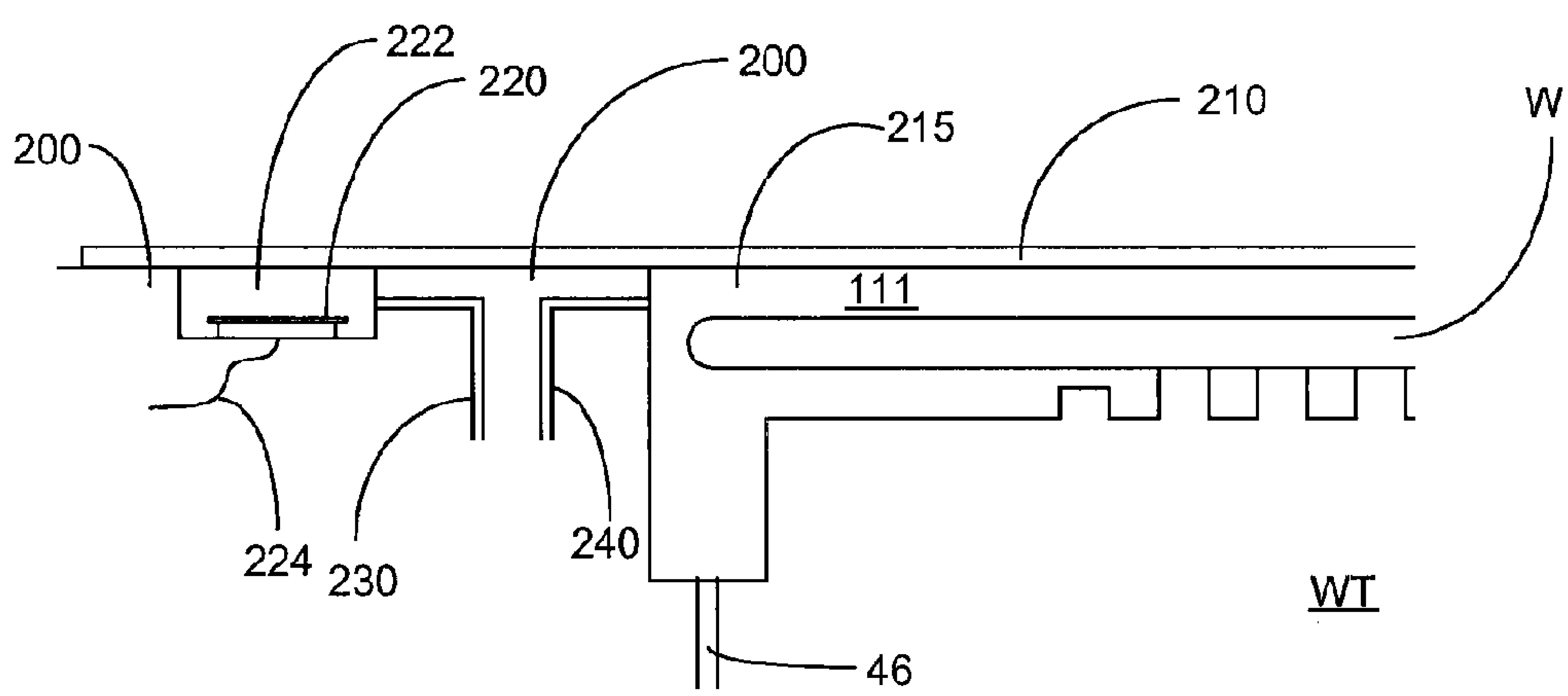
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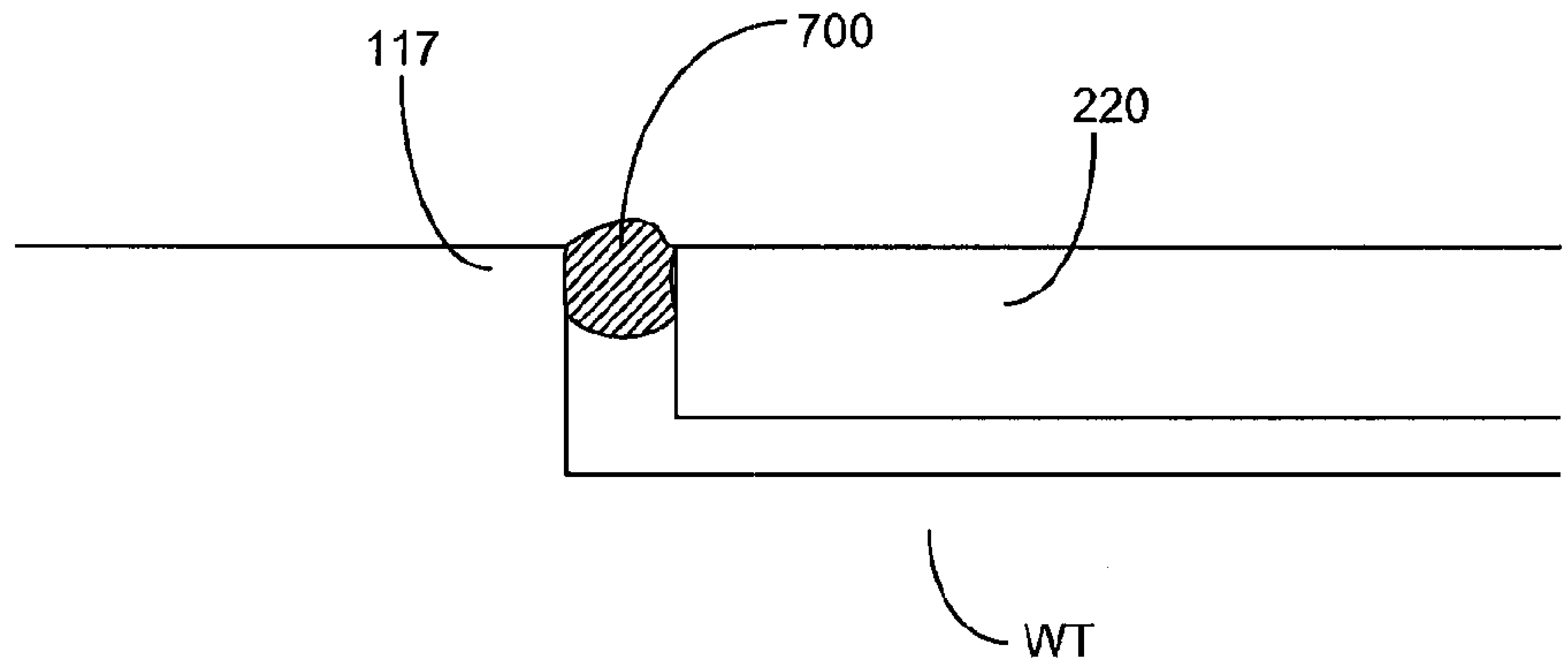
Fig. 11



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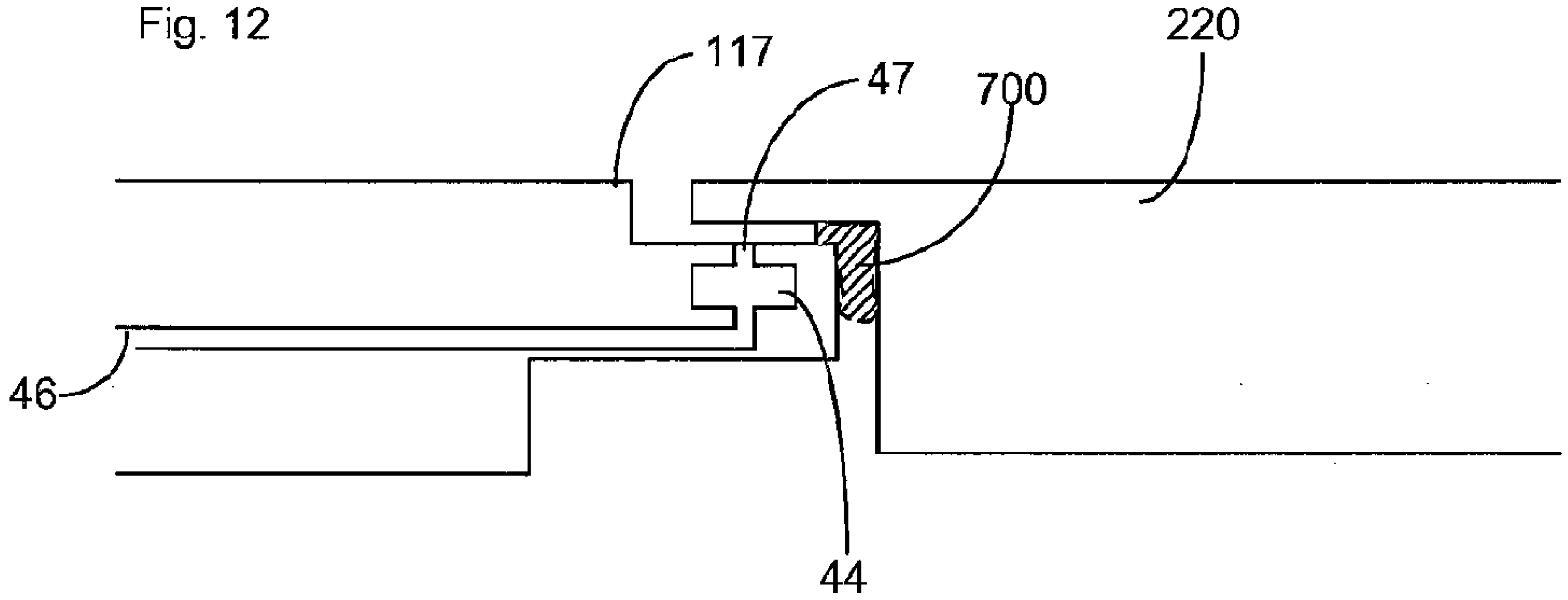

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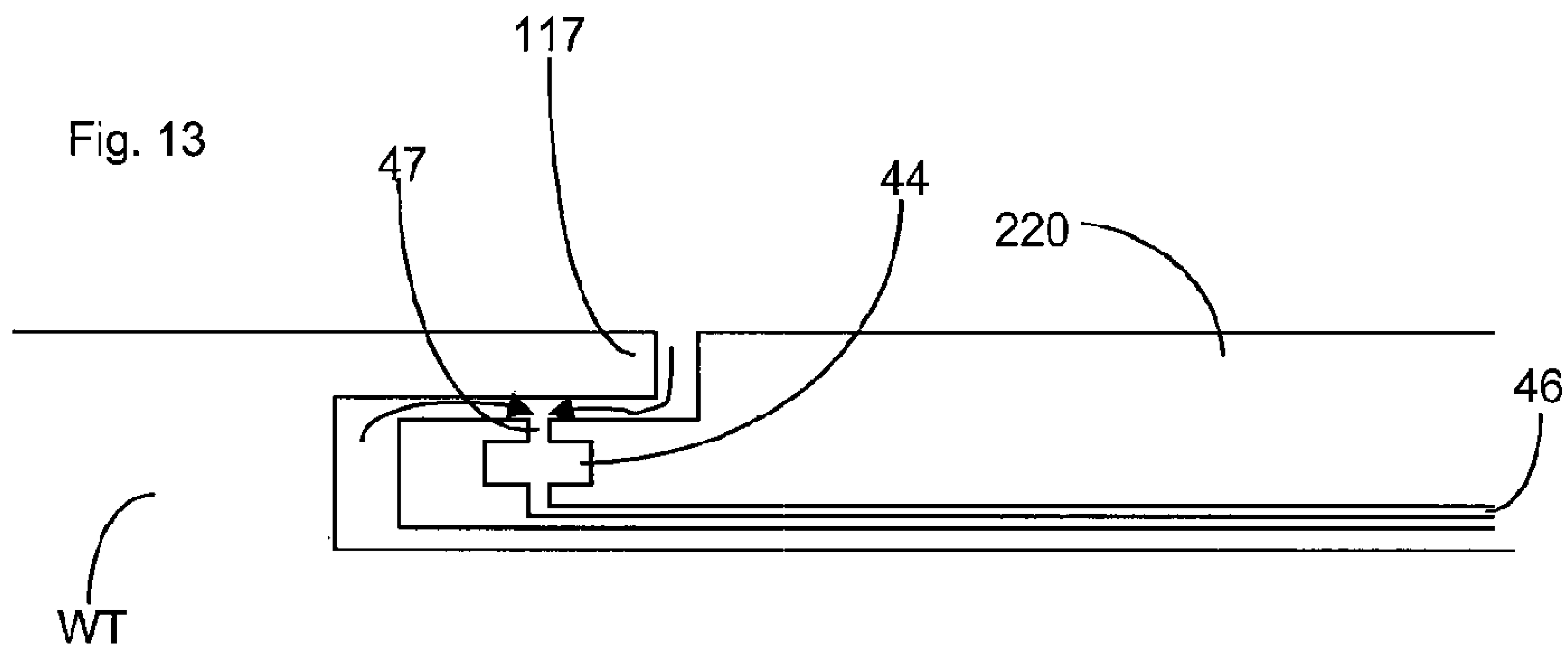

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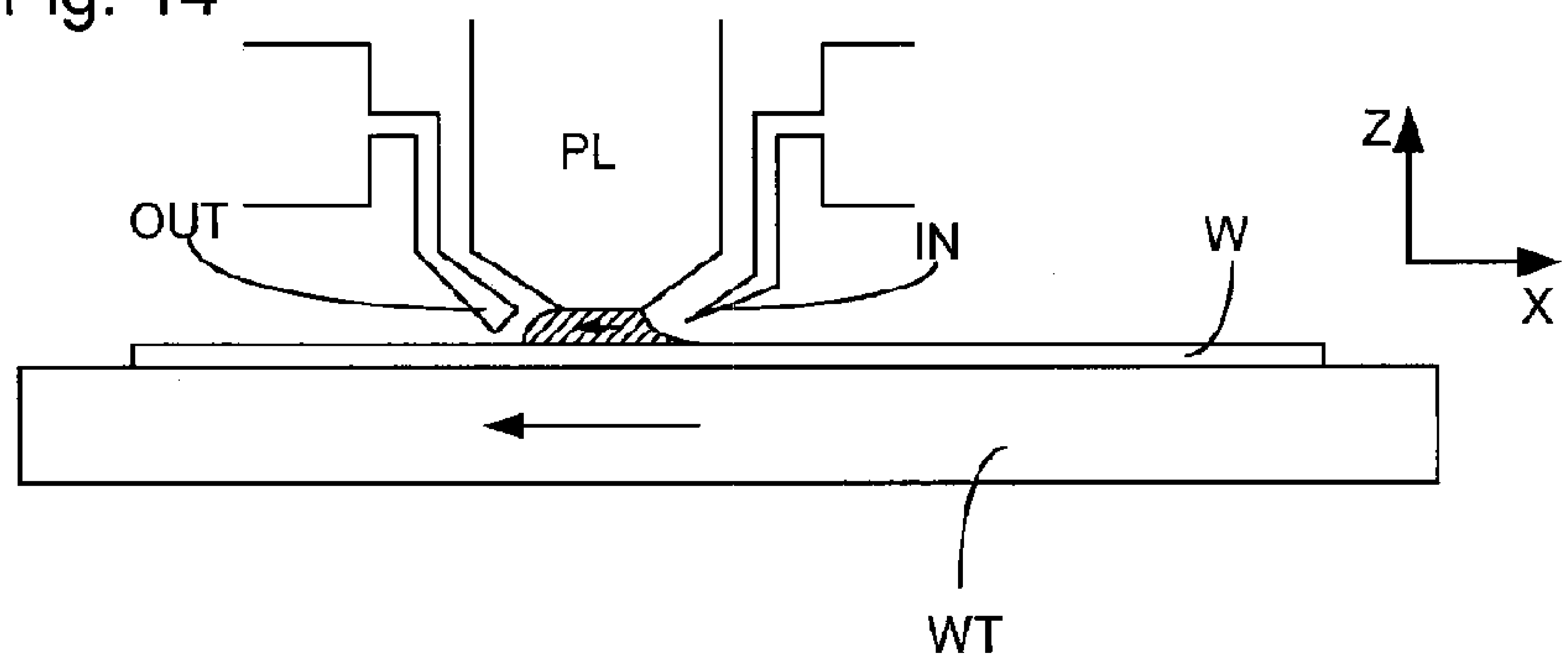

Fig. 15

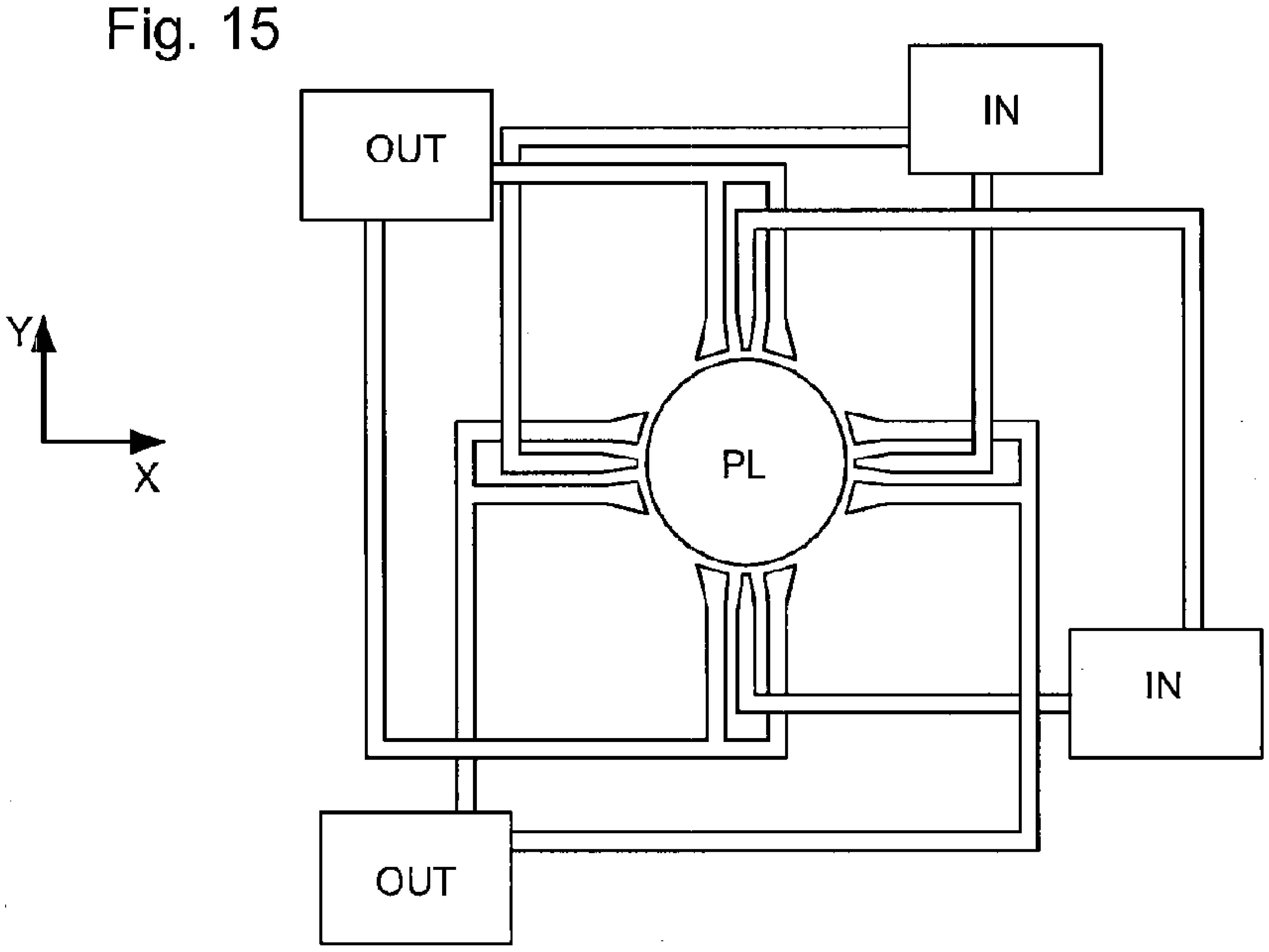

Fig. 16

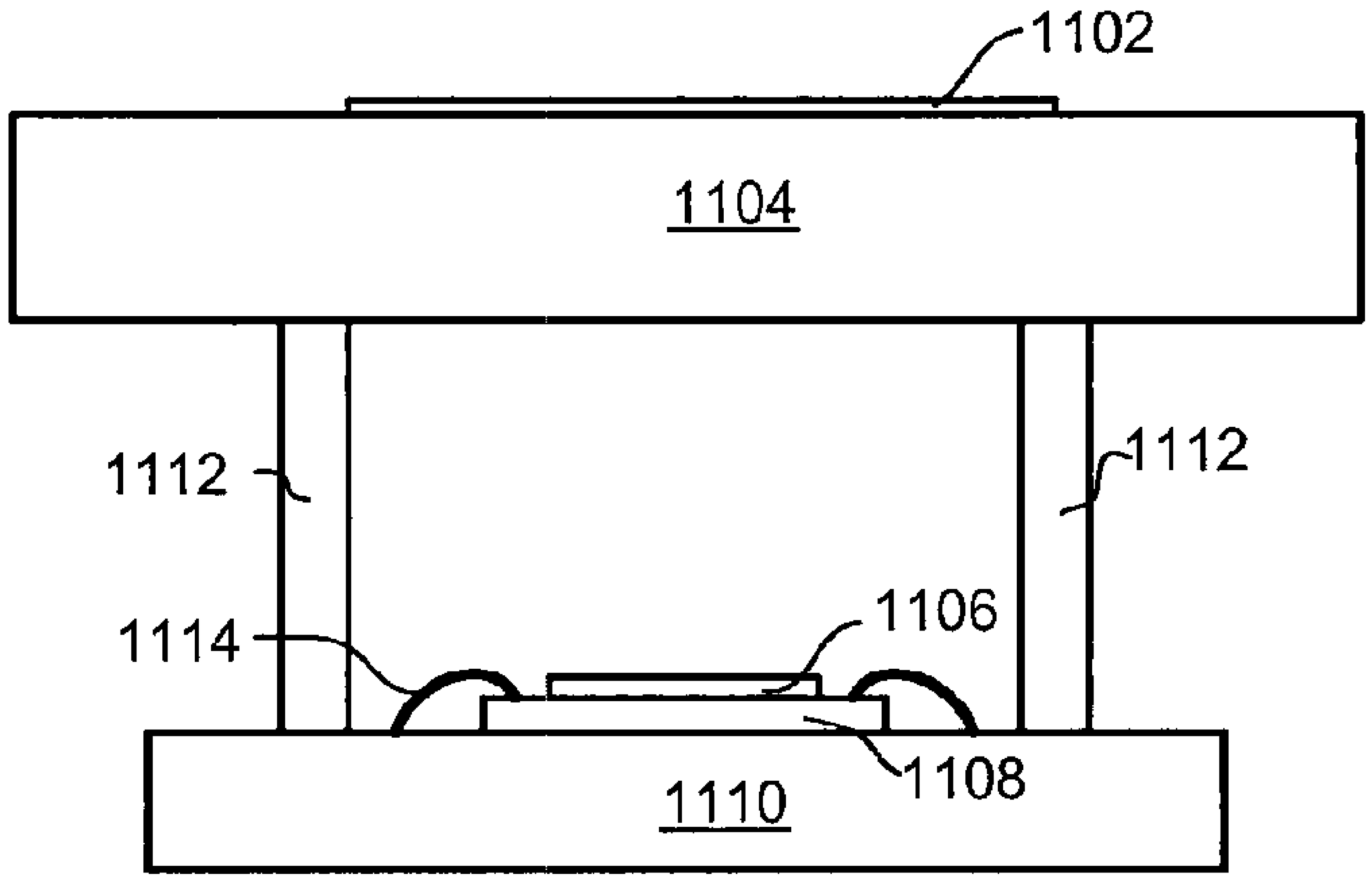
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Fig. 17

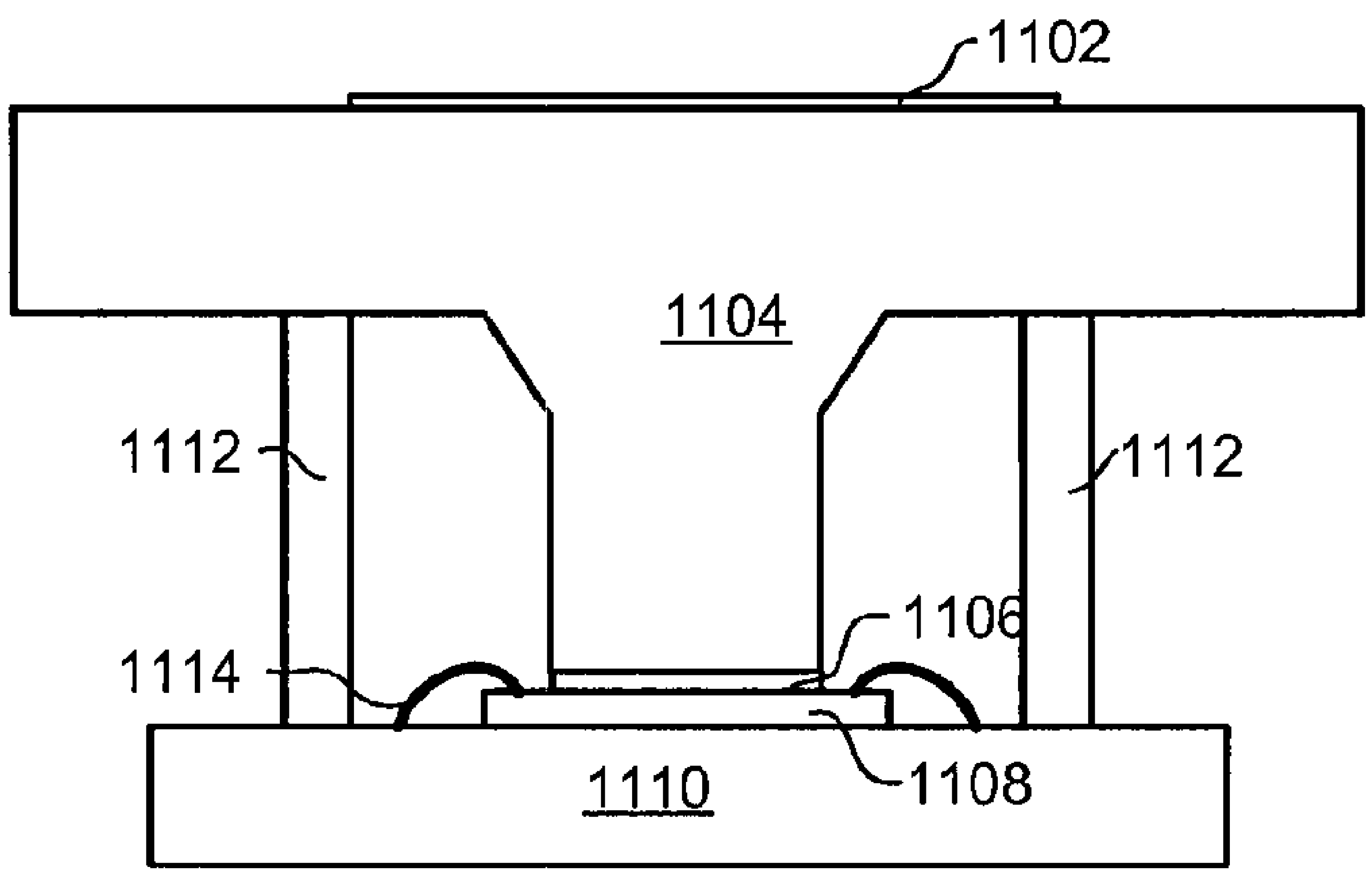
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Fig. 18

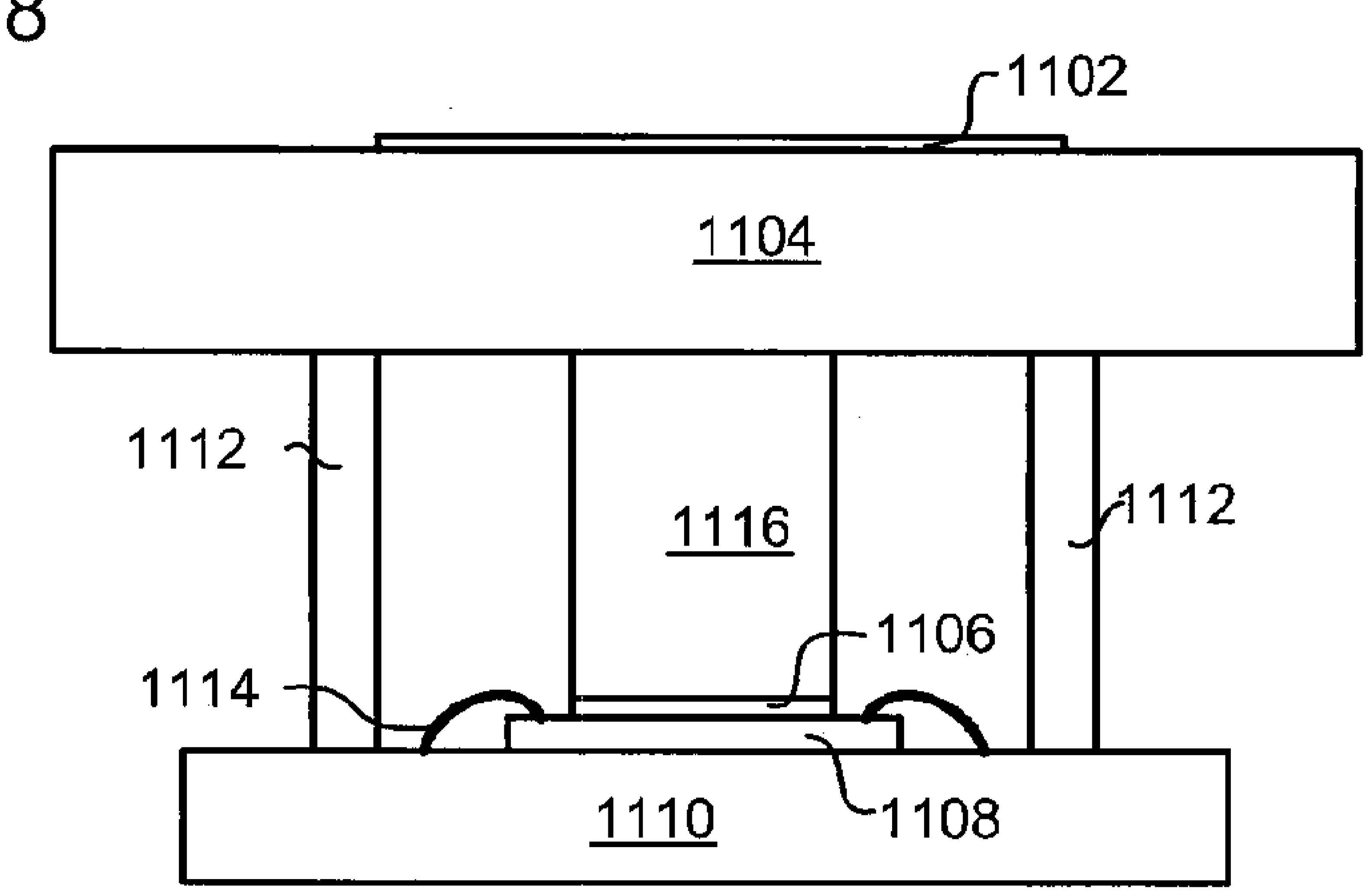


Fig. 19a

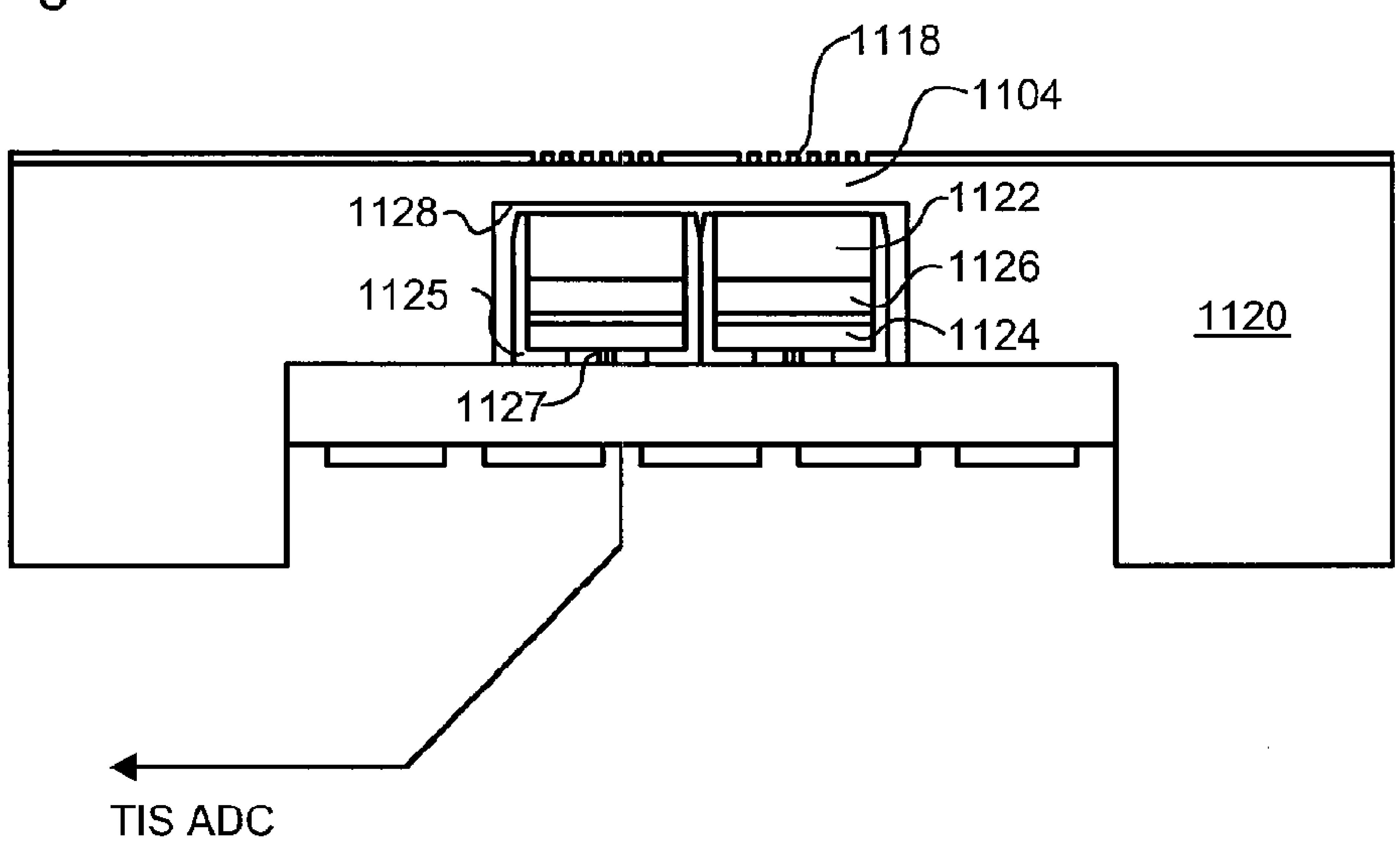
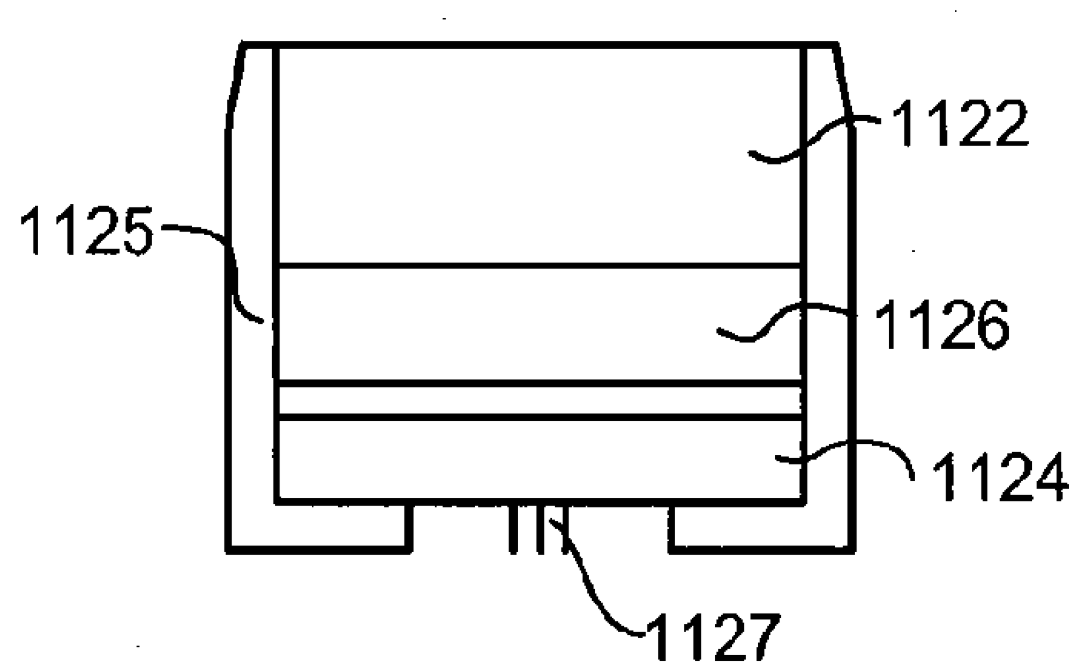


Fig. 19b



LITHOGRAPHIC APPARATUS AND DEVICE MANUFACTURING METHOD INVOLVING A MEMBER AND A FLUID OPENING

This application is a continuation application of U.S. patent application Ser. No. 12/698,932, filed Feb. 2, 2010, now U.S. Pat. No. 8,482,845 which is a continuation application of U.S. patent application Ser. No. 11/482,122, filed Jul. 7, 2006, now U.S. Pat. No. 8,154,708 which is a continuation application of U.S. patent application Ser. No. 10/857,614, filed Jun. 1, 2004, now U.S. Pat. No. 7,213,963, which in turn claims priority from European patent applications EP 03253636.9, filed Jun. 9, 2003, EP 03255395.0, filed Aug. 29, 2003, and EP 03257068.1, filed Nov. 10, 2003, each foregoing application incorporated herein in its entirety by reference.

FIELD

The present invention relates to a lithographic projection apparatus and a device manufacturing method.

BACKGROUND

The term "patterning device" as here employed should be broadly interpreted as referring to any device that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" can also be used in this context. Generally, the pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of such a patterning device include:

A mask. The concept of a mask is well known in lithography, and it includes mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. In the case of a mask, the support structure will generally be a mask table, which ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired.

A programmable mirror array. One example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-addressable surface. An alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted about an axis by applying a suitable localized electric field, or by employing piezoelectric actuation means. Once again, the mirrors are matrix-addressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors; in this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The matrix addressing can be performed using suitable electronics. In both of the situations described hereabove, the patterning device can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be gleaned, for example, from U.S. Pat. No. 5,296,891 and U.S. Pat. No. 5,523,193, and PCT patent application publications WO 98/38597 and WO 98/33096, which are incorporated herein by reference. In the case of a programmable mirror array, the support structure may be embodied as a frame or table, for example, which may be fixed or movable as required.

A programmable LCD array. An example of such a construction is given in U.S. Pat. No. 5,229,872, which is incorporated herein by reference. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required.

For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask and mask table; however, the general principles discussed in such instances should be seen in the broader context of the patterning device as hereabove set forth.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning device may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (e.g. comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion at one time; such an apparatus is commonly referred to as a stepper. In an alternative apparatus—commonly referred to as a step-and-scan apparatus—each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally <1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned, for example, from U.S. Pat. No. 6,046,792, incorporated herein by reference.

In a manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

For the sake of simplicity, the projection system may hereinafter be referred to as the "projection lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in U.S. Pat. No. 5,969,441 and PCT patent application publication WO 98/40791, incorporated herein by reference.

It has been proposed to immerse the substrate in a lithographic projection apparatus in a liquid having a relatively high refractive index, e.g. water, so as to fill the space between the final optical element of the projection system and the substrate. The point of this is to enable imaging of smaller features because the exposure radiation will have a shorter wavelength in the liquid than in gas (e.g., air) or in a vacuum. (The effect of the liquid may also be regarded as increasing the effective NA of the system).

However, submersing the substrate or substrate and substrate table in a bath of liquid (see for example U.S. Pat. No. 4,509,852, hereby incorporated in its entirety by reference) means that there is a large body of liquid that must be accelerated during a scanning exposure. This requires additional or more powerful motors and turbulence in the liquid may lead to undesirable and unpredictable effects.

One of the solutions proposed is for a liquid supply system to provide liquid on only a localized area of the substrate and in between the final element of the projection system and the substrate (the substrate generally has a larger surface area than the final element of the projection system). One way which has been proposed to arrange for this is disclosed in PCT patent application publication WO 99/49504, hereby incorporated in its entirety by reference. As illustrated in FIGS. **14** and **15**, liquid is supplied by at least one inlet IN onto the substrate, preferably along the direction of movement of the substrate relative to the final element, and is removed by at least one outlet OUT after having passed under the projection system. That is, as the substrate is scanned beneath the element in a −X direction, liquid is supplied at the +X side of the element and taken up at the −X side. FIG. **15** shows the arrangement schematically in which liquid is supplied via inlet IN and is taken up on the other side of the element by outlet OUT which is connected to a low pressure source. In the illustration of FIG. **14** the liquid is supplied along the direction of movement of the substrate relative to the final element, though this does not need to be the case. Various orientations and numbers of in- and out-lets positioned around the final element are possible, one example is illustrated in FIG. **23** in which four sets of an inlet with an outlet on either side are provided in a regular pattern around the final element.

SUMMARY

Accordingly, it would be advantageous, for example, to provide an immersion lithographic projection apparatus with improved functionality.

According to an aspect of the invention, there is provided a lithographic projection apparatus comprising:

an illuminator adapted to condition a beam of radiation;

a support structure configured to hold a patterning device, the patterning device configured to pattern the beam of radiation according to a desired pattern;

a substrate table configured to hold a substrate;

a projection system adapted to project the patterned beam onto a target portion of the substrate;

a liquid supply system configured to at least partly fill a space between the projection system and an object on the substrate table, with a liquid; and

a sensor capable of being positioned to be illuminated by the beam of radiation once it has passed through the liquid.

By passing a beam of radiation for a sensor through liquid, no elaborate measures need to be taken to compensate the signals from the sensor to take account of the parameters measured by the sensor being measured through a different medium to that which the substrate is imaged through. However, it may be necessary to ensure that the design of the sensor is such that it is compatible for use when covered with liquid. An example sensor includes an alignment sensor configured to align the substrate table relative to the projection system, a transmission image sensor, a focus sensor, a spot or dose sensor, an integrated lens interferometer and scanner sensor and even an alignment mark. In the case of an alignment sensor, the measurement gratings of the sensor may have a pitch than less than 500 nm, such pitch possibly improving the resolution of the alignment sensor.

According to a further aspect of the present invention, there is provided a device manufacturing method comprising:

projecting a beam of radiation through a liquid onto a sensor; and

projecting the beam of radiation as patterned using a projection system of a lithographic apparatus through the liquid onto a target portion of a substrate.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

In the present document, the terms "radiation" and "beam" are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (e.g. with a wavelength of 365, 248, 193, 157 or 126 nm).

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts:

FIG. **1** depicts a lithographic projection apparatus according to an embodiment of the invention;

FIG. **2** depicts the liquid reservoir of a first embodiment of the invention;

FIG. **3** illustrates a second embodiment of the invention;

FIG. **4** illustrates an alternative form of the second embodiment of the present invention;

FIG. **5** illustrates a detail of the second embodiment of the present invention;

FIG. **6***a* illustrates a first version of a third embodiment of the present invention;

FIG. **6***b* illustrates a second version of the third embodiment;

FIG. **6***c* illustrates a third version of the third embodiment;

FIG. **7** illustrates in detail further aspects of the first version of the third embodiment of the present invention;

FIG. **8** illustrates a fourth embodiment of the present invention;

FIG. **9** illustrates an fifth embodiment of the present invention;

FIG. **10** illustrates a sixth embodiment of the present invention;

FIG. **11** illustrates a seventh embodiment of the present invention;

FIG. **12** illustrates an eighth embodiment of the present invention;

FIG. **13** illustrates a eighth embodiment of the present invention;

FIG. **14** illustrates an alternative liquid supply system according to an embodiment of the invention;

FIG. **15** illustrates, in plan, the system of FIG. **14**;

FIG. **16** depicts an ILIAS sensor module;

FIG. **17** depicts an ILIAS sensor module with an elongated transmissive plate according to an embodiment of the present invention;

FIG. **18** depicts an ILIAS sensor module with a filler sheet according to an embodiment of the present invention; and

FIGS. **19***a* and **19***b* depict a luminescence based DUV transmission image sensor.

DETAILED DESCRIPTION

Embodiment 1

FIG. **1** schematically depicts a lithographic projection apparatus according to a particular embodiment of the invention. The apparatus comprises:

- a radiation system Ex, IL, for supplying a projection beam PB of radiation (e.g. DUV radiation), which in this particular case also comprises a radiation source LA;
- a first object table (mask table) MT provided with a mask holder for holding a mask MA (e.g. a reticle), and connected to a first positioning device for accurately positioning the mask with respect to item PL;
- a second object table (substrate table) WT provided with a substrate holder for holding a substrate W (e.g. a resist-coated silicon wafer), and connected to a second positioning device for accurately positioning the substrate with respect to item PL;
- a projection system ("projection lens") PL (e.g. a refractive system) for imaging an irradiated portion of the mask MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

As here depicted, the apparatus is of a transmissive type (e.g. has a transmissive mask). However, in general, it may also be of a reflective type, for example (e.g. with a reflective mask). Alternatively, the apparatus may employ another kind of patterning device, such as a programmable mirror array of a type as referred to above.

The source LA (e.g. an excimer laser) produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expander Ex, for example. The illuminator IL may comprise adjusting means AM for setting the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

It should be noted with regard to FIG. **1** that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser. The current invention and claims encompass at least both of these scenarios.

The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having traversed the mask MA, the beam PB passes through the projection system PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning device (and interferometric measuring device IF), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the beam PB. Similarly, the first positioning device can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval of the mask MA from a mask library, or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in FIG. **1**. However, in the case of a stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed.

The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected at one time (i.e. a single "flash") onto a target portion C. The substrate table WT is then shifted in the X and/or Y directions so that a different target portion C can be irradiated by the beam PB;

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the Y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed V=Mv, in which M is the magnification of the projection system PL (typically, M=¼ or ⅕). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

FIG. **2** shows a liquid reservoir **10** between the projection system PL and the substrate W which is positioned on the substrate stage WT. The liquid reservoir **10** is filled with a liquid **11** having a relatively high refractive index, e.g. water or a suspension of particles in water, provided via inlet/outlet ducts **13**. The liquid has the effect that the radiation of the projection beam is a shorter wavelength in the liquid than in gas (e.g., air) or in a vacuum, allowing smaller features to be resolved. It is well known that the resolution limit of a projection system is determined, inter alia, by the wavelength of the projection beam and the numerical aperture of the system. The presence of the liquid may also be regarded as increasing the effective numerical aperture. Furthermore, at fixed numerical aperture, the liquid is effective to increase the depth of field.

The reservoir **10** forms, in an embodiment, a contactless seal to the substrate W around the image field of the projection system PL so that the liquid is confined to fill the space between the substrate's primary surface, which faces the projection system PL, and the final optical element of the projection system PL. The reservoir is formed by a seal member **12** positioned below and surrounding the final element of the projection system PL. Thus, the liquid supply system provides liquid on only a localized area of the substrate. The seal member **12** forms part of the liquid supply system for filling the space between the final element of the projection system and the substrate with a liquid. This liquid is brought into the space below the projection system and within the seal member **12**. In an embodiment, the seal member **12** extends a little above the bottom element of the projection system and the liquid rises above the final element so that a buffer of liquid is provided. The seal member **12** has an inner periphery that at the upper end closely conforms to the shape of the projection system or the final elements thereof and may, e.g. be round. At the bottom the inner periphery closely conforms to the shape of the image field, e.g. rectangular, though this is not necessarily so. The seal member is substantially stationary in the XY plane relative to the projection system though there may be some relative movement in the Z direction (in the direction of the optical axis). A seal is formed between the seal member and the surface of the substrate. In an implementation, this seal is a contactless seal and may be a gas seal.

The liquid **11** is confined in the reservoir **10** by a seal device **16**. As illustrated in FIG. **2**, the seal device is a contactless seal i.e. a gas seal. The gas seal is formed by gas, e.g. air or synthetic air, provided under pressure via inlet **15** to the gap between seal member **12** and substrate W and extracted by first outlet **14**. The over pressure on the gas inlet **15**, vacuum level or under pressure on the first outlet **14** and the geometry of the gap are arranged so that there is a high-velocity gas flow inwards towards the optical axis of the apparatus that confines the liquid **11**. As with any seal, some liquid is likely to escape, for example up the first outlet **14**.

FIGS. **14** and **15** also depict a liquid reservoir defined by inlet(s) **1**N, outlet(s) OUT, the substrate W and the final element of projection system PL. Like the liquid supply system of FIG. **2** the liquid supply system illustrated in FIGS. **14** and **15**, comprising inlet(s) IN and outlet(s) OUT, supplies liquid to the primary surface of the substrate in a localized area between the final element of the projection system and the substrate and can suffer from loss of liquid at the substrate edge.

Thus, as used herein for the embodiments, the liquid supply system can comprise that as described in relation to FIG. **2** and FIGS. **14** and **15**.

Embodiment 2

A second embodiment is illustrated in FIGS. **3** to **5** and is the same or similar as the first embodiment except as described below.

In the embodiment of FIGS. **3** and **4** an edge liquid supply system provides liquid to a reservoir **30** via a port **40**. The liquid in the reservoir **30** is optionally the same as the immersion liquid in the liquid supply system. The reservoir **30** is positioned on the opposite side of the substrate W to the projection system PL and adjacent the edge of the substrate W and the edge of the edge seal member **17**, **117**. In FIG. **4**, the edge seal member **17** is comprised of an element which is separate to the substrate table WT whereas in FIG. **3** the edge seal member **117** is provided by an integral portion of the substrate table WT. As can be seen most clearly from FIG. **3**, the substrate W is supported on the substrate table WT by a so-called pimple table **20**. The pimple table **20** comprises a plurality of projections on which the substrate W rests. The substrate W is held in place by, e.g., a vacuum source sucking the substrate onto the top surface of the substrate table WT. With the use of the reservoir **30**, when the edge of the substrate W is being imaged, (i.e. when liquid in the liquid supply system between the projection system PL and the substrate W traverses across an edge of the substrate W), liquid cannot escape from the liquid supply system into the gap between the edge seal member **17**, **117** and the substrate W because that space is already filled with liquid.

The mechanism **170** shown in FIG. **4** for moving the edge seal member **17** relative to the remainder of the substrate table WT is illustrated in detail in FIG. **5**. The reason for moving the edge seal member **17** in this way is so that its primary surface can be made to be substantially co-planar with the primary surface of the substrate W. This allows a smooth movement of the liquid supply system over edge portions of the substrate W so that the bottom inner periphery of the liquid supply system can be moved to positions partly on the primary surface of substrate W and partly on the primary surface of the edge seal member **17**.

A level sensor (not illustrated) is used to detect the relative heights of the primary surfaces of the substrate W and the edge seal member **17**. Based on the results of the level sensor, control signals are sent to the actuator **171** in order to adjust the height of the primary surface of the edge seal member **17**. A closed loop actuator could also be used for this purpose.

In an implementation, the actuator **171** is a rotating motor which rotates a shaft **176**. The shaft **176** is connected to a circular disc at the end distal to the motor **171**. The shaft **176** is connected away from the centre of the disc. The disc is located in a circular recess in a wedge portion **172**. Ball bearings may be used to reduce the amount of friction between the circular disc and the sides of the recess in the wedge portion **172**. The motor **171** is held in place by leaf springs **177**. On actuation of the motor the wedge portion is driven to the left and right as illustrated (i.e. in the direction of the slope of the wedge portion) because of the excentre position of the shaft **176** in the disc. The motor is prevented from moving in the same direction as the direction of movement of the wedge portion **172** by the springs **177**.

As the wedge portion **172** moves left and right as illustrated in FIG. **5**, its top surface **175** (which is the surface of the wedge which is sloped in relation to the primary surface of the edge seal member **17**) contacts the bottom sloped surface of a further wedge member **173** which is fixed to the bottom of the edge seal member **17**. The edge seal member **17** is prevented from moving in the direction of movement of the wedge member **172** so that when the wedge member **172** moves left and right the edge seal member **17** is lowered and raised respectively. Some biasing of the edge seal member **17** towards the substrate table WT may be necessary.

Obviously the further wedge member **173** could be replaced by an alternative shape, for example a rod positioned perpendicularly to the direction of movement of the wedge **172**. If the coefficient of friction between the wedge member **172** and the further wedge member **173** is greater than the tangent of the wedge angle then the actuator **170** is self-braking meaning that no force may be needed on the wedge member **172** to hold it in place. This is advantageous as the system will then be stable when the actuator **171** is not actuated. The accuracy of the mechanism **170** is of the order of a few μm.

Especially in the case of the edge seal member **117** being an integral part of the substrate table WT, a mechanism may be provided to adjust the height of the substrate W or the member supporting the substrate W so that the primary surfaces of the edge seal member **17**, **117** and the substrate can be made substantially co-planar.

Embodiment 3

A third embodiment is illustrated in FIGS. **6** and **7** and is the same or similar as the first embodiment except as described below.

This embodiment is described in relation to an edge seal member **117** which is an integral part of the substrate table WT. However, this embodiment is equally applicable to an edge seal member **17** which is movable relative to the substrate table WT.

In a first version of this embodiment as illustrated in FIG. **6***a*, a further edge seal member **500** is used to bridge the gap between the edge seal member **117** and the substrate W. The further edge seal member is affixed to the edge seal member **117**. The further edge seal member **500** is removably attachable against the surface of the substrate W opposite the primary surface. In this embodiment the further edge seal member **500** can be a flexible edge seal member which is actuatable to contact the under surface of the substrate W. When the flexible edge seal member **500** is deactivated it falls away from the substrate under gravity. The way this is achieved is illustrated in FIG. **7** and is described below.

It is likely that the further edge seal member **500** will not prevent all of the immersion liquid from the liquid supply system from entering the space under the substrate W and for this reason a port **46** connected to a low pressure source may be provided under the substrate W adjacent edges of the edge seal member **117** and the substrate W in some or all of the versions of this embodiment. Of course the design of the area under the substrate could be the same as that of the second embodiment.

The same system can be used for sensors such as a transmission image sensor (TIS) on the substrate table as opposed for the substrate W. In the case of sensors, as the sensors do not move, the further edge seal member **500** can be permanently attached to the sensor, for example using glue.

Furthermore, the further edge seal member **500** can be arranged to engage with the top surface of the object (that surface closest to the projection system) rather than the bottom surface. Also, the further edge seal member **500** may be provided attached to or near the top surface of the edge seal member **117** as opposed to under the edge seal member **117** as is illustrated in FIG. **6***a*.

A second version of this embodiment is illustrated in FIG. **6***b*. Two further edge seal members **500***a*, **500***b* are used. The first of these edge seal members **500***a* is the same as in the first version. The second of these edge seal members **500***b* is affixed to the substrate table **20** i.e. underneath the substrate W and extends with its free end radially outwardly from its attachment point. The second further edge seal member **500***b* clamps the first further edge seal member **500***a* against the substrate W. Compressed gas can be used to deform or move the second further edge seal member **500***b*.

A third version of this embodiment is shown in FIG. **6***c*. The third version is the same as the second version except the first further edge seal member **500***c* clamps the second further edge seal member **500***d* to the substrate W. This avoids, for example, the need for the compressed gas of the second version.

It will be appreciated that the embodiment will also work with only the second further edge seal member **500***b*, **500***d* with or without connection to vacuum.

Various ways of deforming the further edge seal members **500**, **500***a*, **500***b*, **500***c*, **500***d* will now be described in relation to the first version of the embodiment.

As can be seen from FIG. **7**, a channel **510** is formed in the elongate direction of a flexible further edge seal member **500** (which, in an implementation, is an annular ring) and (a) discrete port(s) are provided in an upper surface of the flexible further edge seal member which faces the projection system PL and the underside of the substrate W. By connecting a vacuum source **515** to the duct **510** the flexible further edge seal member can be made to abut the substrate W by suction. When the vacuum source **515** is disconnected or switched off, the flexible further edge seal member **500** drops under gravity and/or pressure from port **46** to assume the position shown in dotted lines in FIG. **7**.

In an alternative or additional embodiment, a flexible further edge seal member **500** is formed with a mechanical pre-load such that it contacts the substrate W when the substrate is placed on the pimple table **20** and the flexible further edge seal member **500** deforms elastically so that it applies a force upwards on the substrate W to thereby make a seal.

In a further alternative or additional embodiment, a flexible further edge seal member **500** may be forced against the substrate W by an overpressure generated by pressurised gas on port **46**.

A flexible further edge seal member **500** may be fashioned from any flexible, radiation and immersion liquid resistant, non-contaminating material, for example, steel, glass e.g. Al_2O_3, ceramic material e.g. SiC, Silicon, Teflon, low expansion glasses (e.g. Zerodur™ or ULE™), carbon fibre epoxy or quartz and is typically between 10 and 500 μm thick, optionally between 30 and 200 μm or 50 to 150 μm in the case of glass. With a flexible further edge seal member **500** of this material and these dimensions, the typical pressure to be applied to the duct **510** is approximately 0.1 to 0.6 bar.

Embodiment 4

A fourth embodiment is illustrated in FIG. **8** and is the same or similar as the first embodiment except as described below.

This embodiment is described in relation to an edge seal member **117** which is an integral part of the substrate table WT. However, this embodiment is equally applicable to an edge seal member **17** which is movable relative to the substrate table WT.

In the fourth embodiment, the gap between the edge seal member **117** and the substrate W is filled with a further edge seal member **50**. The further edge seal member is a flexible further edge seal member **50** which has a top surface which is substantially co-planar with the primary surfaces of the substrate W and the edge seal member **117**. The flexible further edge seal member **50** is made of a compliant material so that minor variations in the diameter/width of substrate W and in the thickness of the substrate W can be accommodated by deflections of the flexible further edge seal member **50**. When liquid in the liquid supply system under the projection system PL passes over the edge of the substrate, the liquid cannot escape between the substrate W, flexible further edge seal member **50** and edge seal member **117** because the edges of those elements are tight against one another. Furthermore, because the primary surfaces of the substrate W and the edge seal member **117** and the top surface of the flexible further edge seal member **50** are substantially co-planar, the liquid supply system operation is not upset when it passes over the edge of the substrate W so that disturbance forces are not generated in the liquid supply system.

As can be seen from FIG. **8**, the flexible further edge seal member **50** is in contact with a surface of the substrate W opposite the primary surface of the substrate W, at an edge portion. This contact has two functions. First, the fluid seal between the flexible further edge seal member **50** and the substrate W may be improved. Second, the flexible further edge seal member **50** applies a force on the substrate W in a direction away from the pimple table **20**. When the substrate W is held on the substrate table WT by, e.g. vacuum suction, the substrate can be held securely on the substrate table. However, when the vacuum source is switched off or disconnected, the force produced by the flexible further edge seal member **50** on the substrate W is effective to push the substrate W off the substrate table WT thereby aiding loading and unloading of substrates W.

The flexible further edge seal member **50** is made of a radiation and immersion liquid resistant material such as PTFE.

Embodiment 5

FIG. **9** illustrates a fifth embodiment which is the same or similar as the first embodiment except as described below.

This embodiment is described in relation to an edge seal member **117** which is an integral part of the substrate table WT. However, this embodiment is equally applicable to an edge seal member **17** which is movable relative to the substrate table WT.

As can be seen from FIG. **9**, the eighth embodiment includes a further edge seal member **100** for bridging the gap between the edge seal member **117** and the substrate W. In this case the further edge seal member **100** is a gap seal member which is positioned on the primary surfaces of the substrate W and the edge seal member **117** to span the gap between the substrate W and edge seal member **117**. Thus, if the substrate W is circular, the gap seal member **100** will also be circular (annular).

The gap seal member **100** may be held in place by the application of a vacuum **105** to its underside (that is a vacuum source exposed through a vacuum port on the primary surface of the edge seal member **117**). The liquid supply system can pass over the edge of the substrate W without the loss of liquid because the gap between the substrate W and the edge seal member **117** is covered over by the gap seal member **100**. The gap seal member **100** can be put in place and removed by the substrate handler so that standard substrates and substrate handling can be used. Alternatively the gap seal member **100** can be kept at the projection system PL and put in place and removed by appropriate mechanisms (e.g. a substrate handling robot). The gap seal member **100** should be stiff enough to avoid deformation by the vacuum source. Advantageously the gap seal member **100** is less than 50, optionally **30** or **20** or even 10 μm thick to avoid contact with the liquid supply system, but should be made as thin as possible

The gap seal member **100** is advantageously provided with tapered edges **110** in which the thickness of the gap seal member **100** decreases towards the edges. This gradual transition to the full thickness of the gap seal member ensures that disturbance of the liquid supply system is reduced when it passes on top of the gap seal member **100**.

The same way of sealing may be used for other objects such as sensors, for example transmission image sensors. In this case, as the object is not required to move, the gap seal member **100** can be glued in place (at either end) with a glue which does not dissolve in the immersion liquid. The glue can alternatively be positioned at the junction of the edge seal member **117**, the object and the gap seal member **100**.

Furthermore, the gap seal member **100** can be positioned underneath the object and an overhang of the edge seal member **117**. The object may be shaped with an overhang also, if necessary.

The gap seal member **100**, whether above or below the object, can have a passage provided through it, from one opening in a surface in contact with the edge seal member **117** to another opening in a surface in contact with the object. By positioning one opening in fluid communication with vacuum **105**, the gap seal member **100** can then be kept tightly in place.

Embodiment 6

A sixth embodiment will be described with reference to FIG. **10**. The solution shown in FIG. **10** bypasses some of the problems associated with imaging edge portions of the substrate W as well as allows a transmission image sensor (TIS) **220** (or other sensor or object) to be illuminated by the projection system PL under the same conditions as the substrate W.

The sixth embodiment uses the liquid supply system described with respect to the first embodiment. However, rather than confining the immersion liquid in the liquid supply system under the projection system PL on its lower side with the substrate W, the liquid is confined by an intermediary plate **210** which is positioned between the liquid supply system and the substrate W. The spaces **222**, **215** between the intermediary plate **210** and the TIS **220** and the substrate W are also filled with liquid **111**. This may either be done by two separate space liquid supply systems via respective ports **230**, **240** as illustrated or by the same space liquid supply system via ports **230**, **240**. Thus the space **215** between the substrate W and the intermediary plate **210** and the space **222** between the transmission image sensor **220** and the intermediary plate **210** are both filled with liquid and both the substrate W and the transmission image sensor can be illuminated under the same conditions. Portions **200** provide a support surface or surfaces for the intermediary plate **210** which may be held in place by vacuum sources.

The intermediary plate **210** is made of such a size that it covers all of the substrate W as well as the transmission image sensor **220**. Therefore, no edges need to be traversed by the liquid supply system even when the edge of the substrate W is imaged or when the transmission image sensor is positioned under the projection system PL. The top surface of the transmission image sensor **220** and the substrate W are substantially co-planar.

The intermediary plate **210** can be removable. It can, for example, be put in place and removed by a substrate handling robot or other appropriate mechanism.

All of the above described embodiments may be used to seal around the edge of the substrate W. Other objects on the substrate table WT may also need to be sealed in a similar way, such as sensors including sensors and/or marks which are illuminated with the projection beam through the liquid such as a transmission image sensor, integrated lens interferometer and scanner (wavefront sensor) and a spot sensor plate. Such objects may also include sensors and/or marks which are illuminated with non-projection radiation beams such as levelling and alignment sensors and/or marks. The liquid supply system may supply liquid to cover all of the object in such a case. Any of the above embodiments may be used for this purpose. In some instances, the object will not need to be removed from the substrate table WT as, in contrast to the substrate W, the sensors do not need to be removed from the substrate table WT. In such a case the above embodiments may be modified as appropriate (e.g. the seals may not need to be moveable).

Embodiment 7

FIG. **11** shows a seventh embodiment which is the same as the first embodiment except as described below.

In the seventh embodiment the object on the substrate table WT is a sensor **220** such as a transmission image sensor (TIS). In order to prevent immersion liquid seeping underneath the sensor **220**, a bead of glue **700** which is undissolvable and unreactable with the immersion fluid is positioned between the edge seal member **117** and the sensor **220**. The glue is covered by immersion fluid in use.

Embodiment 8

An eighth embodiment is described with reference to FIGS. **12** and **13**. In the eighth embodiment it is a sensor **220** which is being sealed to the substrate table WT. In both versions illustrated in FIGS. **12** and **13**, a vacuum **46** is provided adjacent the gap with an opening passage **47** and a chamber **44** for taking away any immersion liquid which should find its way through the gap between the edge seal member **117** and the edge of the sensor **220**.

In the FIG. **12** version, the vacuum **46** is provided in the substrate table WT under an overhang portion of the object **220**. The passage **47** is provided in an overhanging inwardly protruding portion of the substrate table WT. Optionally a bead of glue **700** is positioned at the inner most edge of the protruding portion between the substrate table WT and the object **220**. If no bead of glue **700** is provided, a flow of gas from underneath the object **220** helps seal the gap between the sensor **220** and the substrate table WT.

In the version of FIG. **13**, the vacuum **46**, compartment **44** and passage **47** are provided in the object **220** itself under an inwardly protruding edge seal member **117**. Again there is the option of providing a bead of glue between the object **220** and the substrate table WT radially outwardly of the passage **47**.

The shape of the edge seal member **117** and the top outer most edge of the object **220** can be varied. For example, it may be advantageous to provide an overhanging edge seal member **117** or indeed an outer edge of the object **220** which is overhanging. Alternatively, an outer upper corner of the object **220** may be useful.

Example of High NA Detection Sensor

Substrate-level sensors according to one or more embodiments of the invention may comprise a radiation-receiving element (**1102**, **1118**) and a radiation-detecting element (**1108**, **1124**) as shown in FIGS. **16-19**. Exposure radiation is directed from the final element of the projection system PL through an immersion liquid **11** at least partly filling a space between the final element of the projection system PL and the substrate W. The detailed configuration of each of these elements depends on the properties of the radiation to be detected. The sensor at substrate level may comprise a photocell only, for use in cases where it is desirable for the photocell to receive the radiation directly. Alternatively, the sensor at substrate level may comprise a luminescence layer in combination with a photocell. In this arrangement, radiation at a first wavelength is absorbed by the luminescence layer and reradiated a short time later at a second (longer) wavelength. This arrangement is useful, for example, where the photocell is designed to work more efficiently at the second wavelength.

The radiation-receiving element (**1102**, **1118**), which may be a layer with a pinhole, a grating or another diffractive element fulfilling a similar function, may be supported on top of a quartz sensor body **1120**, i.e. on the same side of the body as the projection system. The radiation-detecting element (**1108**, **1124**), in contrast, may be arranged within the sensor body **1120**, or within a concave region formed on the side of the sensor body **1120** facing away from the projection system.

At boundaries between media of different refractive indices a proportion of incident radiation will be reflected and potentially lost from the sensor. For optically smooth surfaces, the extent to which this occurs depends on the angle of incidence of the radiation and the difference in refractive index of the media in question. For radiation incident at and above a "critical angle" (conventionally measured from normal incidence) total internal reflection may occur, leading to serious loss of signal to later elements of the sensor. This may be a particular problem in high NA systems where radiation may have a higher average angle of incidence. Accordingly, in an embodiment, arrangements are provided so that gas is excluded from the region between the radiation-receiving (**1102**, **1118**) and radiation-detecting (**1108**, **1124**) elements in order to avoid interfaces between media of high refractive index and gas.

In addition to losses due to partial and total internal reflection, absorption may also seriously reduce the intensity of radiation intensity reaching the photocell, as may scattering from interfaces that are not optically smooth.

FIG. **16** shows an integrated lens interferometer and scanner (ILIAS) sensor module. This module has a shearing grating structure **1102** as a radiation-receiving element, supported by a transmissive plate **1104**, which may be made of glass or quartz. A quantum conversion layer **1106** is positioned immediately above a camera chip **1108** (the radiation-detecting element), which is in turn mounted on a substrate **1110**. The substrate **1110** is connected to the transmissive plate **1104** via spacers **1112** and bonding wires **1114** connect the radiation-detecting element to external instrumentation. A gas gap is located between the quantum conversion layer **1106** and the transmissive plate **1104**. In a setup such as this designed for 157 nm radiation, for example, the gas gap within the sensor cannot easily be purged so that it will contain significant proportions of oxygen and water, which absorb radiation. Signal is therefore lost and the effect becomes worse for larger angles as these have a longer path length through gas. Thus, the dynamic range requirements for the sensor become more severe.

FIGS. **17** and **18** show improved ILIAS sensor modules according to embodiments of the present invention. In FIG. **17**, the gas gap has been removed by changing the shape of the transmissive plate **1104** to fit directly to the camera **1108**. This arrangement is made more difficult by the need to provide access for the bonding wires **1114** and necessitates an elongated form. From an engineering point of view, the alternative arrangement shown in FIG. **18** is easier to realize. Here, a filler sheet **1116** of the same material as the transmissive plate **1104**, or of similar optical properties, is inserted between the transmissive plate **1104** and the quantum conversion layer **1106**. The removal of the gas gap reduces transmission losses and relaxes dynamic range requirements (or, alternatively speaking, improves the effective dynamic range). Both arrangements improve refractive index matching and reduce the extent of spurious internal reflections at the interface with the transmissive plate **1104**.

FIG. **19***a* shows a DUV transmission image sensor. FIG. **19***b* shows a magnified view of the processing element for clarity. The pattern of transmissive grooves **1118**, constituting the radiation-receiving element in this case, is realized by means of e-beam lithography and dry etching techniques in a thin metal layer deposited on a substrate by means of sputtering. DUV radiation that is projected towards the grooves **1118** is transmitted by the transmissive plate **1104** (which may be quartz or fused silica) and hits the underlying luminescent material **1122**, or "phosphor". The luminescent material **1122** may comprise a slab of crystalline material that is doped with rare-earth ions, e.g. yttrium-aluminium-garnet doped with cerium (YAG:Ce). The main purpose of the luminescent material **1122** is to convert the DUV radiation into more easily detectable visible radiation, which is then detected by the photodiode **1124**. DUV radiation that has not been absorbed and converted into visible radiation by the phosphor **1122** may be filtered out before it reaches the photodiode **1124** (e.g. by a BG-39 or UG filter **1126**).

In the above arrangement, gas may be present in the gaps between components mounted in the sensor housing **1125**, yielding a number of gas/material/gas interfaces that interrupt the propagation of radiation. By considering the path of DUV radiation and radiation arising from luminescence, it is possible to identify regions where radiation is likely to be lost. The first region of interest is the rear-side **1128** of the transmissive plate **1104**, reached by DUV radiation after it has passed through the grooves **1118** and transmissive plate **1104**. Here, the surface has been formed by mechanical means, such as by drilling, and is inevitably rough on the scale of the wavelength of the radiation. Radiation may therefore be lost due to scattering, either back into the transmissive plate **1104** or out past the luminescent material **1122**. Secondly, after this interface, the DUV light encounters the optically smooth gas/YAG:Ce interface, where a substantial amount of reflection may occur due to the refractive index mismatch, particularly in systems of high NA. Thirdly, the luminescent material **1122** emits radiation in random directions. Due to its relatively high refractive index, the critical angle for total internal reflection at a YAG:Ce/air boundary is around 33° (where, for example, there is air in the gap between the YAG:Ce and the filter **1126**) from the normal, meaning that a large proportion of radiation incident on the boundary is reflected out of the system and lost through the side walls of the luminescent material **1122**. Finally, the part of the luminescence that is directed towards the photodiode has to overcome the gas/quartz interface on the diode surface where surface roughness may again account for loss of detected signal.

Each of the embodiments may be combined with one or more of the other embodiments as appropriate. Further, each of the embodiments (and any appropriate combination of embodiments) can be applied simply to the liquid supply system of FIG. **2** and FIGS. **14** and **15** without the edge seal member **17**, **117** as feasible and/or appropriate.

In an embodiment, there is provided a lithographic projection apparatus comprising: an illuminator adapted to condition a beam of radiation; a support structure configured to hold a patterning device, the patterning device configured to pattern the beam of radiation according to a desired pattern; a substrate table configured to hold a substrate; a projection system adapted to project the patterned beam onto a target portion of a substrate; a liquid supply system configured to at least partly fill a space between the projection system and an object on the substrate table, with a liquid; and a sensor capable of being positioned to be illuminated by a beam of radiation once it has passed through the liquid.

In an embodiment, the substrate table comprises a support surface configured to support an intermediary plate between the projection system and the sensor and not in contact with the sensor. In an embodiment, the sensor comprises a transmission image sensor configured to sense the beam and wherein the intermediary plate is positionable between the sensor and the projection system. In an embodiment, the sensor is on the substrate table. In an embodiment, the sensor comprises an alignment sensor configured to align the substrate table relative to the projection system. In an embodiment, measurement gratings of the alignment sensor have a pitch of less than 500 nm. In an embodiment, the alignment sensor is configured to be illuminated obliquely. In an embodiment, the sensor comprises a transmission image sensor. In an embodiment, the sensor comprises a focus sensor. In an embodiment, the sensor comprises a spot or dose sensor, an integrated lens interferometer and scanner, an alignment mark, or any combination of the foregoing. In an embodiment, the substrate table comprises an edge seal member configured to at least partly surround an edge of the sensor and to provide a primary surface facing the projection system substantially co-planar with a primary surface of the sensor. In an embodiment, the sensor is configured to be in contact with the liquid and the beam of radiation is configured to come from the projection system or an alignment system. In an embodiment, the beam of radiation is the patterned beam. In an embodiment, an alignment system comprises the sensor and is configured receive an alignment beam of radiation from the projection system to align the substrate. In an embodiment, the substrate table comprises a vacuum port configured to remove liquid from a space between the substrate table and the sensor. In an embodiment, the apparatus further comprises a bead of material in a space between the substrate table and the sensor configured to prevent entry of the liquid.

In an embodiment, there is provided a device manufacturing method comprising: projecting a beam of radiation through a liquid onto a sensor; and projecting the beam of radiation as patterned using a projection system of a lithographic apparatus through the liquid onto a target portion of a substrate.

In an embodiment, the liquid is supported on an intermediary plate between the projection system and the sensor, the plate not being in contact with the sensor. In an embodiment, the sensor comprises a transmission image sensor configured to sense the beam and the intermediary plate is positionable between the sensor and the projection system. In an embodiment, the sensor is on a substrate table holding the substrate. In an embodiment, the sensor comprises an alignment sensor configured to align a substrate table holding the substrate relative to the projection system. In an embodiment, measurement gratings of the alignment sensor have a pitch of less than 500 nm. In an embodiment, the alignment sensor is configured to be illuminated obliquely. In an embodiment, the sensor comprises a transmission image sensor. In an embodiment, the sensor comprises a focus sensor. In an embodiment, the sensor comprises a spot or dose sensor, an integrated lens interferometer and scanner, an alignment mark, or any combination of the foregoing. In an embodiment, a substrate table holding the substrate comprises an edge seal member configured to at least partly surround an edge of the sensor and to provide a primary surface facing the projection system substantially co-planar with a primary surface of the sensor. In an embodiment, the method comprises projecting the beam of radiation from the projection system or an alignment system through the liquid onto the sensor in contact with the liquid. In an embodiment, the beam of radiation is the patterned beam. In an embodiment, an alignment system comprises the sensor and is configured receive an alignment beam of radiation from the projection system to align the substrate. In an embodiment, a substrate table holding the substrate comprises a vacuum port configured to remove liquid from a space between the substrate table and the sensor. In an embodiment, the method further comprises providing a bead of material in a space between the substrate table and the sensor configured to prevent entry of the liquid.

While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. In particular, the invention is also applicable to other types of liquid supply systems, especially localised liquid area systems. If the seal member solution is used, it may be one in which a seal other than a gas seal is used. The description is not intended to limit the invention.

The invention claimed is:

1. An exposure apparatus comprising:

a movable table comprising a top surface having an object support surface portion to support an object;

a member, movably separate from the table and located on a member support surface portion of the top surface of the table, to provide a surface substantially co-planar with a top surface of the object in or on the table, wherein the object and member support surface portions are substantially co-planar;

a projection system configured to project a radiation beam onto a radiation-sensitive target portion of a substrate; and

a liquid supply system configured to provide a liquid to a space between the projection system and the object, the liquid supply system comprising an inlet to supply the liquid,

wherein the table further comprises a recess recessed into the top surface of the table and extending below the object and member support surface portions and a fluid opening, below a gap opening between the object when supported on the table and the member, to remove the liquid entering the gap opening, the fluid opening being separate from the inlet and in an upwardly facing surface of the recess below the object and member support surface portions, the upwardly facing surface extending on opposite sides of the fluid opening.

2. The apparatus of claim 1, wherein the liquid supply system is configured to substantially confine the liquid to a localized area having a size smaller than the area of the substrate.

3. The apparatus of claim 1, wherein the object comprises a part of a sensor system configured to be illuminated by a beam of radiation through the liquid.

4. The apparatus of claim 1, wherein the object comprises the substrate.

5. The apparatus of claim 1, wherein the fluid opening is below a bottom surface of the member.

6. The apparatus of claim 1, further comprising a vacuum opening located under the member.

7. The apparatus of claim 1, further comprising a liquid confinement structure having a bottom surface, the bottom surface having an outlet configured to remove the liquid from the space, and the liquid confinement structure having an open aperture to allow fluid communication of the supplied liquid between a bottom surface of the projection system and the movable table.

8. An exposure apparatus comprising:

a projection system configured to project a radiation beam onto a radiation-sensitive target portion of a substrate;

a movable table comprising a part of a sensor system configured for illumination by a beam of radiation and comprising a top surface having an object support surface portion to support a further object;

a liquid supply system configured to fill a space between the substrate and the projection system with a liquid via an inlet and configured to provide the liquid to a localized area, having a size smaller than the area of the substrate, on the movable table and/or on the part of the sensor system; and

a plate, located on a plate support surface portion of the top surface of the table and removable from the top surface of the table, at least partly covering an edge of the part of the sensor system, providing a primary surface, facing upward, substantially co-planar with a primary surface of the part of the sensor system, and having an opening to surround the further object in or on the table, wherein the object and plate support surface portions are substantially co-planar,

wherein the table further comprises a recess recessed into the top surface of the table and extending below the object and plate support surface portions and a fluid opening, below a gap opening between the further object when supported on the table and the plate, to remove the liquid entering the gap opening, the fluid opening being separate from the inlet and in an upwardly facing surface of the recess below the object and plate support surface portions, the upwardly facing surface extending on opposite sides of the fluid opening.

9. The apparatus of claim 8, wherein the plate is movable with respect to the part of the sensor system.

10. A device manufacturing method, comprising:

projecting a beam of radiation, using a projection system, through a liquid onto a radiation-sensitive target portion of a substrate;

providing the liquid from an inlet to a space between the projection system and an object in or on a movable table, wherein a member, movably separate from the table and the substrate and located on a member support surface portion of a top surface of the table, provides a surface substantially co-planar with a top surface of the object in or on the table, wherein the movable table comprises an object support surface portion of the top surface of the table to support the object and a recess recessed into the top surface of the table and extending below the object and member support surface portions, wherein the object and member support surface portions are substantially co-planar; and

removing the liquid entering a gap opening, between the member and the object, using a fluid opening of the table that is below the gap opening, the fluid opening being separate from the inlet and in an upwardly facing surface of the recess below the object and member support surface portions, the upwardly facing surface extending on opposite sides of the fluid opening.

11. The method of claim 10, further comprising substantially confining the liquid to a localized area having a size smaller than the area of the substrate.

12. The method of claim 10, wherein the object comprises a part of sensor system illuminated by a beam of radiation through the liquid.

13. The method of claim 10, further comprising applying a vacuum through an opening located under the member.

14. The method of claim 10, wherein the fluid opening is below a bottom surface of the member.

15. An exposure apparatus comprising:

a movable table comprising a top surface having an object support surface portion to support an object;

a member, located on the top surface of the table, to provide a surface substantially co-planar with a top surface of the object in or on the table, the member is movably separate from the table, the member has an opening to surround the object when in or on the table, and the member provides a surface substantially co-planar with a top surface of a further object in or on the table;

a projection system configured to project a radiation beam onto a radiation-sensitive target portion of a substrate; and

a liquid supply system configured to provide a liquid to a space between the projection system and the object, the liquid supply system comprising an inlet to supply the liquid, wherein the table further comprises an upwardly facing recess recessed below the object support surface portion, the recess extending at least partly underneath the member.

16. The apparatus of claim **15**, further comprising a fluid opening below a gap opening between the object when on the table and the member, the fluid opening being separate from the inlet and in a surface of the recess below the object support surface portion.

17. The apparatus of claim **15**, wherein the member is located on a member support surface portion of the top surface of the table, wherein the object and member support surface portions are substantially co-planar.

18. The apparatus of claim **15**, further comprising a liquid confinement structure having a bottom surface, the bottom surface having an outlet configured to remove the liquid from the space, and the liquid confinement structure having an open aperture to allow fluid communication of the supplied liquid between a bottom surface of the projection system and the movable table.

19. The apparatus of claim **15**, wherein the table further comprises a first fluid opening, below a first gap opening between the member and the object, to remove the liquid entering the first gap opening and a second fluid opening, below a second gap opening between the member and a further object in or on the table, to remove the liquid entering the second gap opening, wherein the first and second fluid openings are below a bottom surface of the member.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,152,058 B2
APPLICATION NO. : 13/194136
DATED : October 6, 2015
INVENTOR(S) : Joeri Lof et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page

On Page 2, Item (56) References Cited - U.S. PATENT DOCUMENTS, Column 2, Line 45 delete "2004/0123351 A1 6/2004 Silvestri".

On Page 3, Item (56) References Cited - FOREIGN PATENT DOCUMENTS, Line 17 replace "JO 11-297615 10/1999" with --JP 11-297615 10/1999--.

On Page 3, Item (56) References Cited - FOREIGN PATENT DOCUMENTS, Line 57 delete "JP 2062-5737 1/2002".

On Page 4, Item (56) References Cited - OTHER PUBLICATIONS, Lines 11-15
delete "Third Preliminary Amendment dated Aug. 17, 2005 for U.S. Appl. No. 11/147,265.
Optical Microlithography XV, Proceedings of SPIE, vol. 4691 (2002), "Resolution Enhancement of 157 nm Lithography by Liquid Immersion", M. Switkes et al., pp. 450-466.".

On Page 4, Item (56) References Cited - OTHER PUBLICATIONS, Lines 27-38
delete "G. Owen et al., "1/81μm Optical Lithography," J. Vac. Sci. Technol. B., vol. 10, No. 6, Nov./Dec. 1992 pp. 3032-3036.
H. Hogan, "New Semiconductor Lithography Makes a Splash," Photonics Spectra, Photonics Technology Wand, Oct. 2003 Edition, pp. 1-3.
Matsuyama et al., "Nikon Projection Lens Update," SPIE Microlithography 2004, 5377-65, Mar. 2004.
B.J. Lin, "The k3 coefficient in nonparaxial λ/NA scaling equations equations for resolution, depth of focus, and immersion lithography," J. Microlith., Miorotab., Microsyst., 1(1):7-12 (2002).
European Search Report far EP Patent Appln. No. 03257068.1 dated May 3, 2004.".

Signed and Sealed this
Twenty-sixth Day of April, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

On Page 6, Item (56) References Cited - OTHER PUBLICATIONS, Column 1, Lines 19-20
delete "S. Owa et al., "Immersion lithography; its potential performance and issues", Proceedings of SPIE Vol. 5040, 2003, pgs. 724-733.".

On Page 6, Item (56) References Cited - OTHER PUBLICATIONS, Column 1, Lines 22-23
delete "M. Switkes et al., "Immersion Lithography at 157 nm," MIT Lincoln Lab, Orlando Jan, 2001, December 17, 2001.".

On Page 6, Item (56) References Cited - OTHER PUBLICATIONS, Column 1, Lines 26-27
delete "M. Switkes et al., "Immersion Lithography: Optics for the 50 nm Node," 157 Anvers-1, Sep. 4, 2002.".

On Page 6, Item (56) References Cited - OTHER PUBLICATIONS, Column 1, Lines 32-33
delete "B.J. Lin, "The Paths To Subhalf-Micrometer Optical Lithography," SPIE Vol. 922, Optical/Laser Microlithography (1988), pgs. 256-269.".

On Page 6, Item (56) References Cited - OTHER PUBLICATIONS, Column 2, Lines 1-3
delete "Bbej.A. Hoffnagle et al., "Liquid Immersion Deep-Ultraviolet Interferometric Lithography," J. Vac. Sci. Technol. B., vol. 17, No. 6, Nov./Dec. 1999, pp. 3306-3309.".